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PRELIMINARY ASSESSMENT OF THE LONG ISLAND NATIONAL WILDLIFE REFUGE COMPLEX ENVIRONMENTAL CONTAMINANTS BACKGROUND STUDY FIFTH YEAR RESULTS

U.S. Fish and Wildlife Service
New York Field Office
3817 Luker Road
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August 1997

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EXECUTIVE SUMMARY

This report represents the preliminary results of the fifth year of the multiyear study entitled, "The Long Island National Wildlife Refuge Complex (Complex) Environmental Contaminants Background Survey." The goal of this survey is to establish a baseline of refuge conditions, provide a basis for monitoring, and to assist refuge managers in identifying and mitigating potential impacts to fish and wildlife resources from environmental contaminants.

Sediment and soil were sampled at the largest refuge of the Complex, Wertheim National Wildlife Refuge (NWR), in 1994 and analyzed for inorganic chemical residues. In addition, fish tissue samples were collected to assess inorganic chemical burdens in wildlife.

Sediment collected from Wertheim NWR in 1994 had levels of lead, mercury, zinc, copper, arsenic, cadmium, chromium, iron, and manganese exceeding at least one of the concern levels reviewed. Analysis of sediment samples collected from Wertheim NWR in 1990 and 1991 determined that the same inorganic residues were found to exceed the concern levels (Mann and Karwowski 1991, Mann-Klager and Parris 1993).

All fish tissue samples collected at Wertheim NWR exceeded the predator protection levels for mercury (0.1 μg/g) and chromium (0.2 μg/g) as reported by Eisler (1987, 1988). All but one of the samples exceeded the predator protection levels for selenium (0.5 μg/g) reported in Walsh et al. (1977). Tissue samples from the southern portion of the refuge exceeded the protection level for arsenic (0.5 μg/g) reported in Walsh et al. (1977), but those from the northern area did not.

The 1994 sediment sampling results at Wertheim NWR confirm earlier findings: there is a transport of contaminants onto this refuge. The northern reach of the Carmans River, the mouths of Yaphank Creek and Little Neck Run, and the full length of Big Fish Creek can be considered contaminant accumulation areas. However, elevated levels

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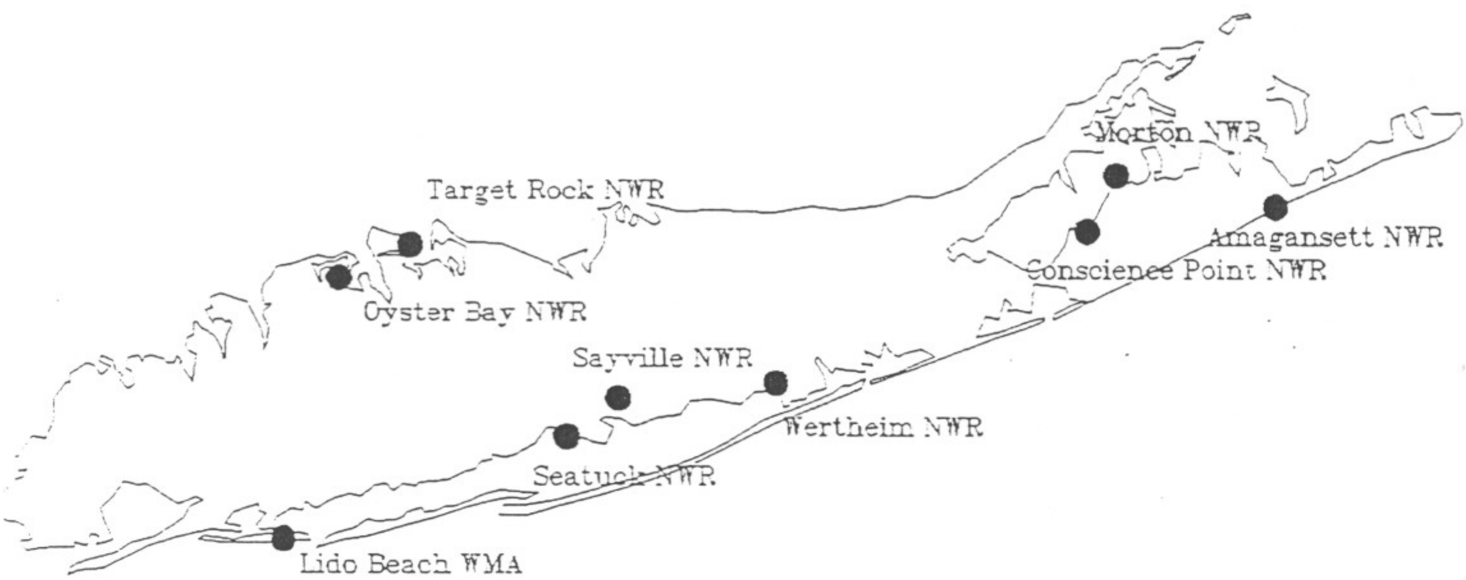
INTRODUCTION

The United States Fish and Wildlife Service (Service) has been entrusted with the responsibility to conserve, protect, and enhance fish and wildlife and their habitats for the continuing benefit of the American people. To meet this responsibility, the environmental health of the National Wildlife Refuge (NWR) System is being assessed to ensure the continued protection of fish and wildlife species using the system. A multiyear study of the Long Island National Wildlife Refuge Complex (Complex) was initiated in 1990 to establish a baseline of refuge conditions, provide a basis for monitoring, and to assist refuge managers in identifying and mitigating potential impacts to fish and wildlife resources from environmental contaminants. The Complex is the last of the three refuge systems in New York State to undergo a contaminants survey; Montezuma NWR and Iroquois NWR background surveys have been completed. This report represents the results of the 1994 sampling survey of Wertheim National Wildlife Refuge, and provides a preliminary assessment of the contaminant burdens in sediments and biota.

The Complex consists of one Wildlife Management Area, Lido Beach, and eight National Wildlife Refuges: Wertheim, Morton, Target Rock, Seatuck, Oyster Bay, Amagansett, Conscience Point, and Sayville (Figure 1). Five of the properties were formerly private estates, three were transferred government properties, and one was donated primarily by a township. These properties are within a rapidly developing coastal region and have been described as "habitat islands" of regionally significant migratory bird stopover, breeding, and wintering habitats (Norton et al. 1984). The refuges provide habitat for several Federal and state designated endangered, threatened, and special concern species, such as the bald eagle (*Haliaeetus leucephalus*), roseate tern (*Sterna dougallii*), peregrine falcon (*Falco peregrinus*), piping plover (*Charadrius melodus*), least tern (*Sterna antillarum*), common tern (*Sterna hirundo*), osprey (*Pandion haliaetus*), eastern bluebird (*Sialia sialis*), northern harrier (*Circus cyaneus*), Eastern hognose snake (*Heterdon platyrhinos*), eastern mud turtle (*Kinosternon subrubrum*), Kemp's ridley sea turtle (*Lepidochelys kempii*), loggerhead sea turtle

Figure 1.

LONG ISLAND NATIONAL WILDLIFE REFUGE COMPLEX

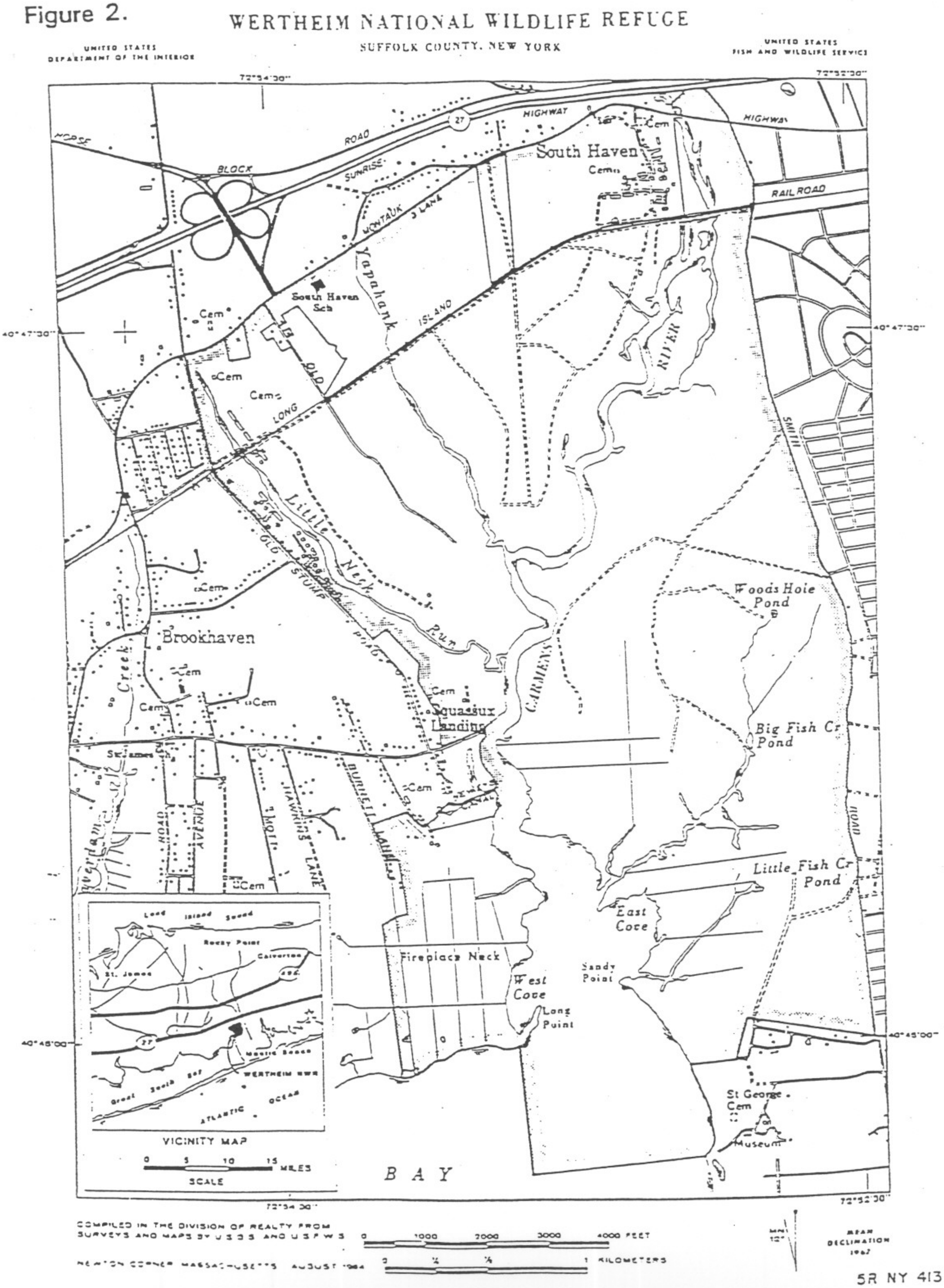


(*Caretta caretta*), leatherback sea turtle (*Dermochelys coriacea*) and sandplain gerardia (*Agalinis acuta*).

The Wertheim National Wildlife Refuge

Wertheim NWR, formerly a private hunting estate, was acquired by gift of deed from Maurice Wertheim on June 6, 1947. The Refuge is bordered by the communities of South Haven, Brookhaven, and Shirley in the Town of Brookhaven in Suffolk County, New York (Figure 2). Wertheim NWR consists of approximately 969 hectares of estuary and upland forest with the Carmans River, a New York State designated wild and scenic river, flowing through its center into Bellport Bay, the eastern most portion of Great South Bay. Habitats at Wertheim include bay, salt marsh, freshwater marsh, shrub swamp, mixed oak forest, oak-pine forest, and pitch pine forest. The Refuge's wetlands provide habitat for breeding waterfowl, especially for wood ducks (*Aix sponsa*), American black ducks (*Anas rubripes*), gadwall (*Anas strepera*), and mallards (*Anas platyrhynchos*). The Carmans River estuary is an important waterfowl wintering area as it is one of the last areas to freeze on Long Island during periodic cold winters. Waterfowl overwintering in this estuary include American black duck, gadwall (*Anas strepera*), bufflehead (*Bucephala albeola*), greater scaup (*Aythya marila*), mallard, hooded merganser (*Lophodytes cucullatus*), red-breasted merganser (*Mergus serrator*), and green-winged teal (*Anas crecca*). Eleven long-legged wading bird species have been documented at Wertheim including American bittern (*Botauus lentiginosus*) and least bittern (*Ixobrychus exilis*), both New York State species of concern. Five pairs of osprey nest on the Refuge and northern harriers are common all year, both New York State designated threatened species. Many species of raptors use Wertheim during migration; most noticeable are sharp-shinned hawks (*Accipiter striatus*), Cooper's hawks (*A. cooperii*), American kestrels (*Falco sparverius*), merlins (*F. columbarius*), and peregrine falcons. Bald eagles occur occasionally during the winter months. The Refuge forest is large and diverse enough to support forest interior breeding birds and most forest dependent avian species known to occur on Long Island. Most species

Figure 2.



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of mammals, reptiles, amphibians, and fish known to occur on Long Island are present at the Refuge. The largest population in New York State of the Eastern mud turtle (*Kinosternon subrubrum subrubrum*), a New York State listed threatened species, is present at Wertheim. A brook trout (*Salvelinus fontinalis*) population occurs on the Refuge, one of only seven on Long Island, and the Carmans River is a significant habitat for yearling striped bass (*Morone saxatilis*) as well as other estuary dependent fish and shellfish.

MATERIALS AND METHODS

SAMPLE SITE LOCATIONS

The Wertheim NWR sediment collection sites were in the Carmans River, Yaphank Creek, Little Neck Run, Big Fish Creek (including the impoundment), Little Fish Creek, and Bellport Bay, as well as a small number of upland sites which bordered the Carmans River and its drainage creeks (Figures 3-5). Sediment samples were collected in August 1994 using a petite ponar dredge. Transects were laid out to sample major habitats of each sample area and potential sources of the contamination. Appendix A provides the sampling protocol. All samples were placed on ice immediately after collection and then frozen until sent on dry ice to the analytical laboratory.

Composite fish tissue samples were collected at selected stations from each area (Figure 6). Samples were placed on ice within one hour of collection. To the extent possible, these stations were selected to correspond to sediment sample locations (Figure 6). Sample species included: killifish (*Fundulus* spp., seven sample sites), American eel (*Rostrata anguilla*, one sample site), and Atlantic silverside (*Menidia menidia*, four sample sites).

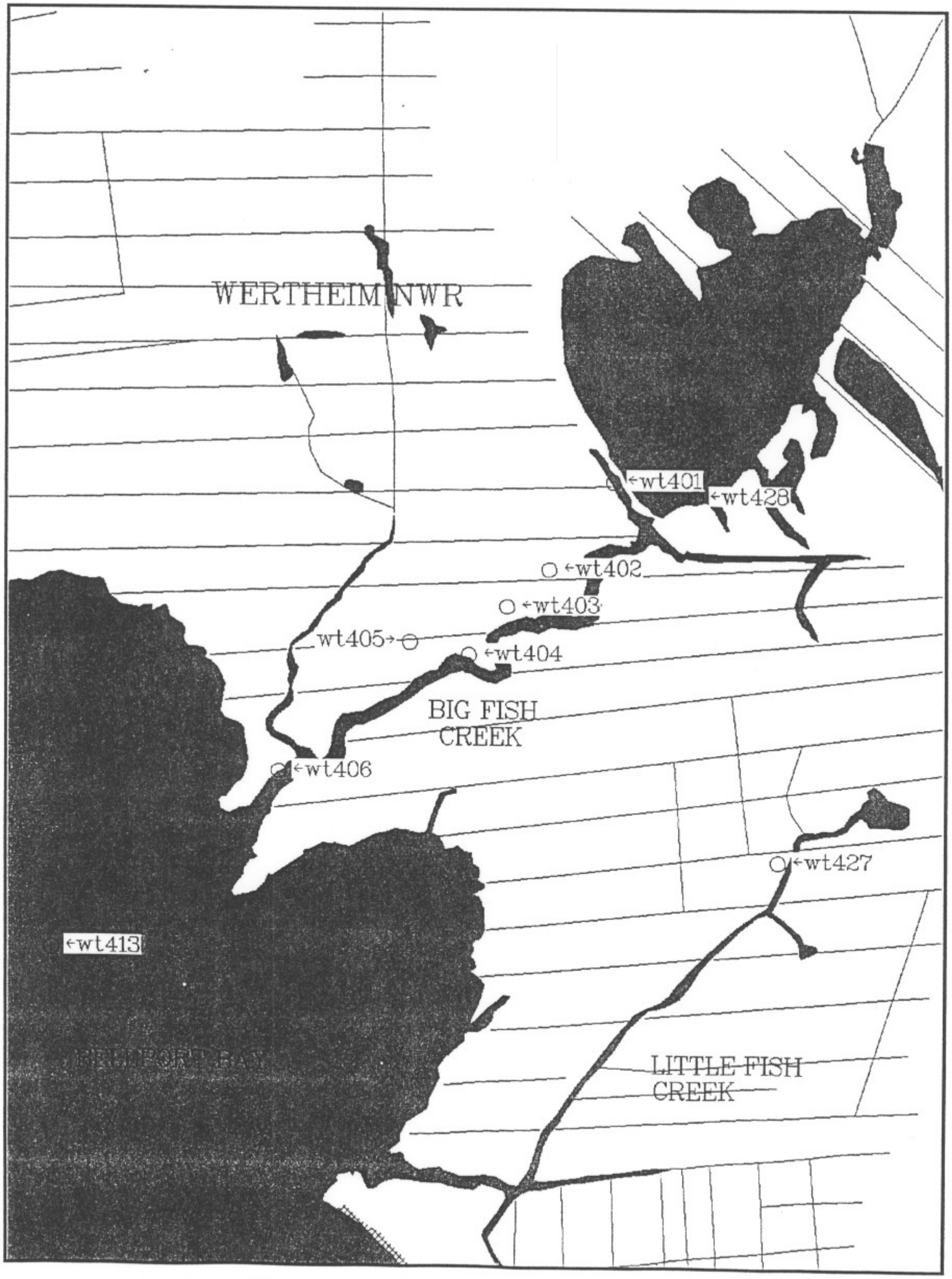

Figure 3. 1994 sediment sample sites in Bellport Bay, Big Fish Creek, and Little Fish Creek, Wertheim National Wildlife Refuge

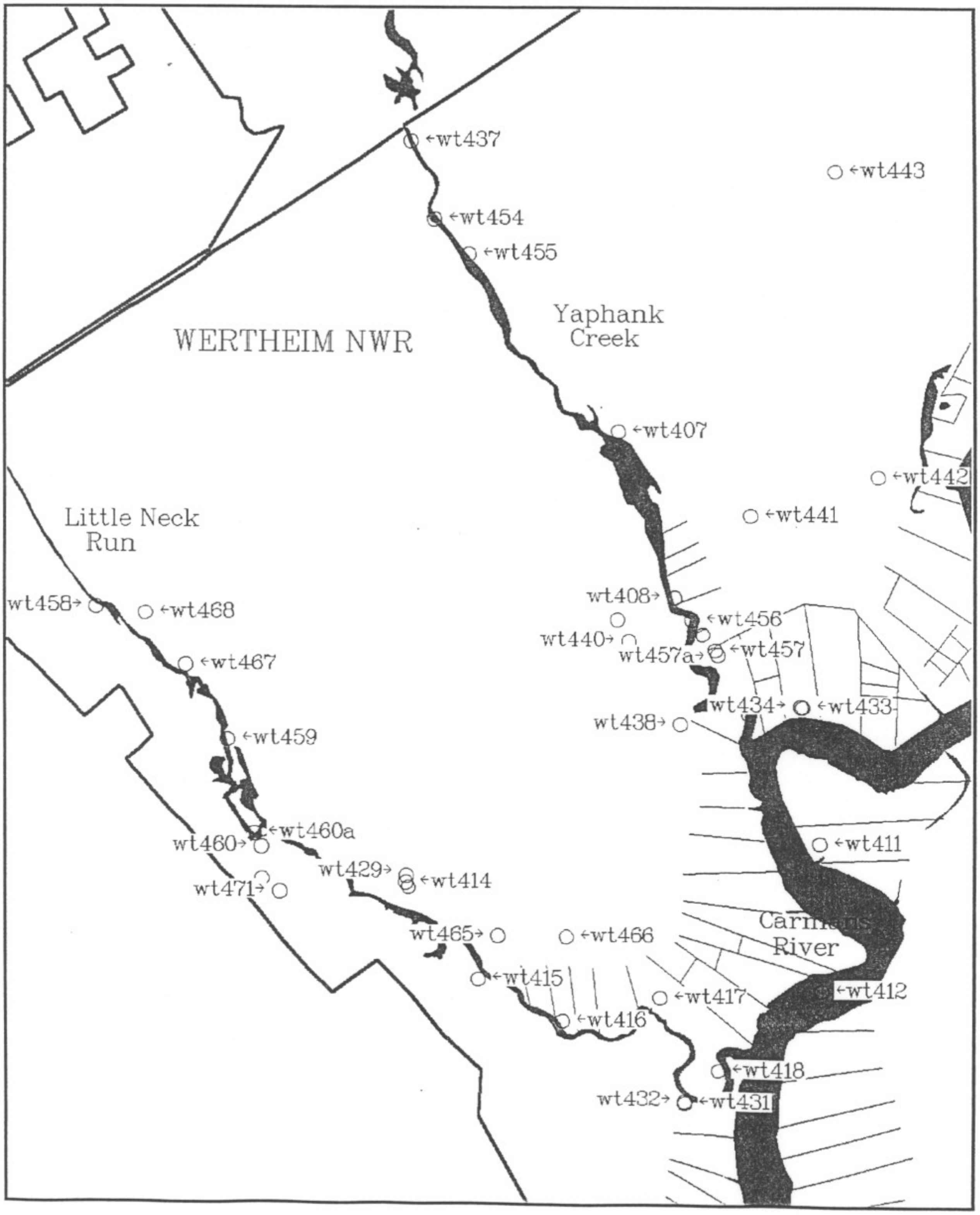

Figure 4. 1994 sediment sample sites in Little Neck Run and Yaphank Creek, Wertheim National Wildlife Refuge

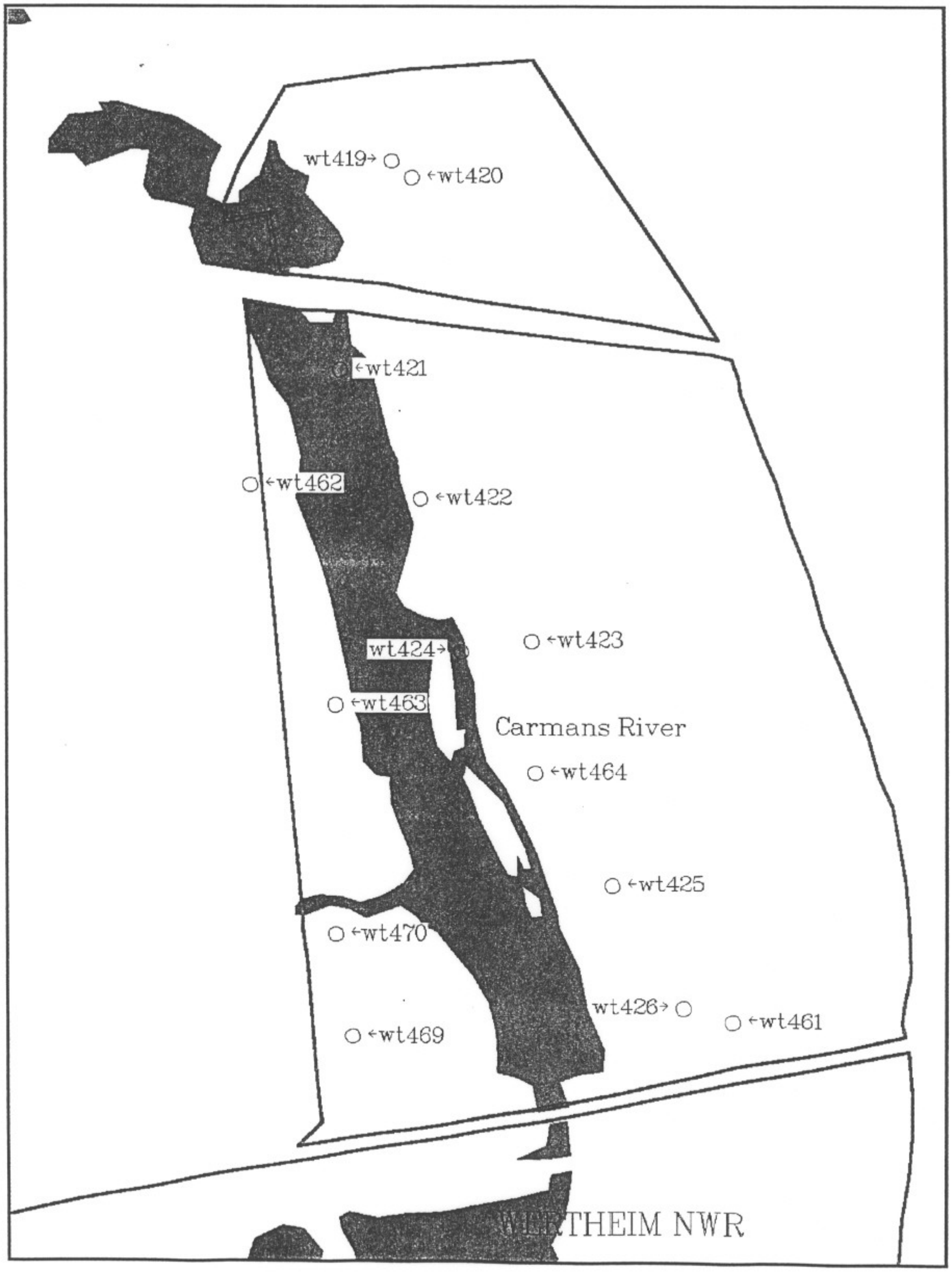

Figure 5. 1994 sediment sample sites in the upper Carmans River, Wertheim National Wildlife Refuge

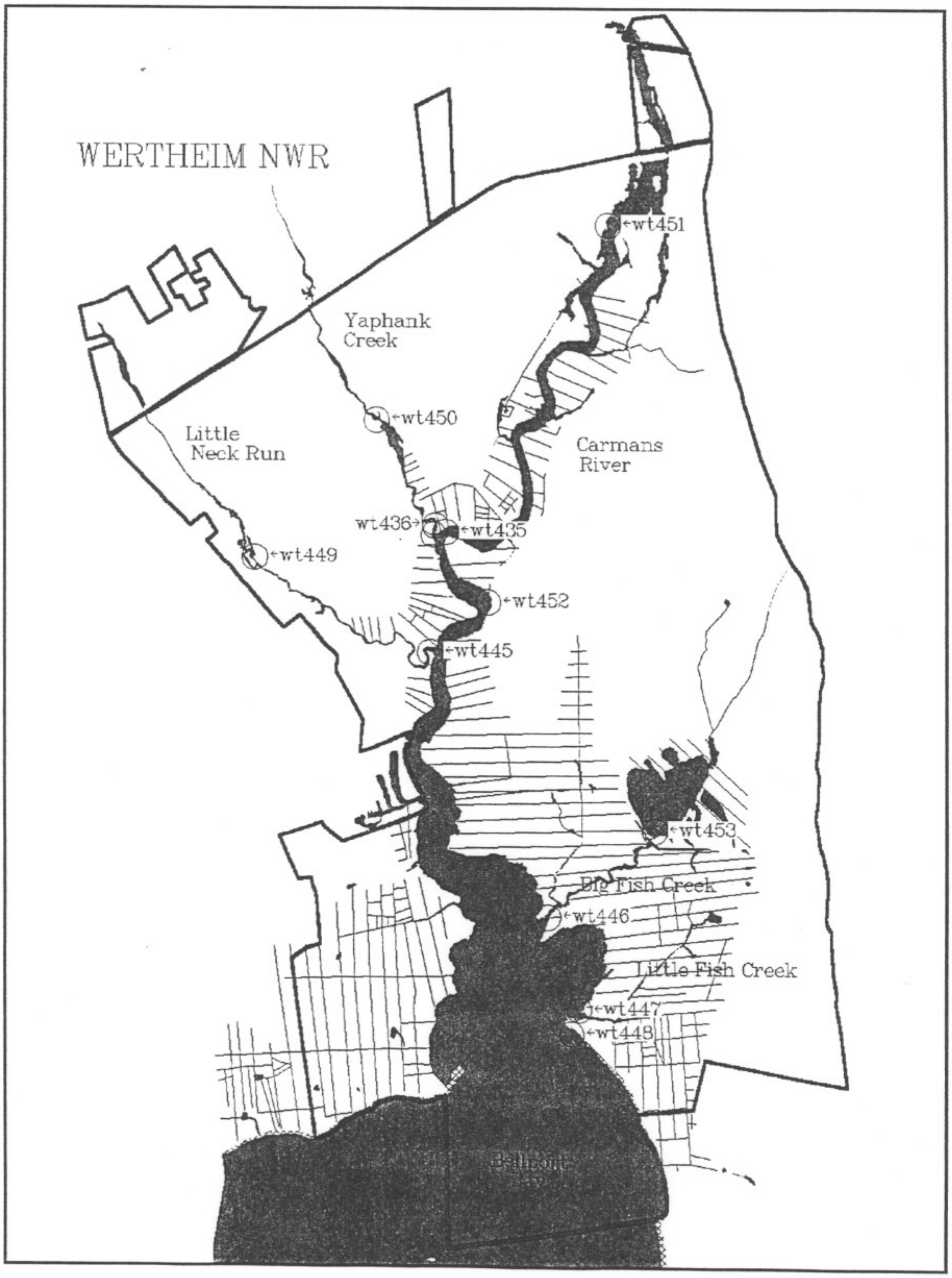

Figure 6. 1994 fish tissue sample sites at Wertheim National Wildlife Refuge

LABORATORY ANALYSIS

The analyses of all samples for inorganic residues were performed following Service contractual specifications at Geochemical & Environmental Research Group, Texas A&M. Quality assurance/quality control (QA/QC) for the analytical techniques used by the contract laboratory was established and overseen by the Patuxent Analytical Control Facility.

Statistical analysis was performed using Lotus 1-2-3, Release 2.2. The technique used was linear regression. In one group of analyses, contaminant concentrations were considered dependent variables while sediment characteristics were the independent variables. In another set of analyses, sediment texture was treated as dependent upon stream position. Significance at the 0.05 and 0.01 levels was determined by comparison to the standard tabular values (Steel and Torrie 1980)

RESULTS

Nineteen inorganic residues were analyzed in the sediment and soil samples (Table 1). As no organic compounds were detected in any of the sediment samples collected from Wertheim NWR in recent surveys, organic analysis was not performed here. While all of the test elements were detected in some samples, detections of molybdenum and selenium were relatively rare. Beryllium and molybdenum were not detected in any of the fish tissue samples collected at Wertheim NWR.

In general, there was a significant ($P < 0.05$) linear correlation between stream position and sediment texture. The percentage of sand dropped significantly and the percentage of silt rose significantly in the downstream direction among sample sites in Big Fish Creek, Little Neck Run, and Carmans River. This trend was not observed in Yaphank Creek. No definite spatial trend was observed for clay content or total organic carbon in any stream. (Table 2).

Table 1. Contaminants analyzed and levels of detection for samples, 1994

Element	Level of Detection (ppm)
Aluminum (Al)	100.0
Arsenic (As)	0.5
Boron (B)	10
Barium (Ba)	3.0
Beryllium (Be)	0.2
Cadmium (Cd)	0.2
Chromium (Cr)	1.0
Copper (Cu)	1.0
Iron (Fe)	100.0
Mercury (Hg)	0.1
Magnesium (Mg)	100.0
Manganese (Mn)	4.0
Molybdenum (Mo)	5.0
Nickel (Ni)	5.0
Lead (Pb)	5.0
Selenium (Se)	1.0
Strontium (Sr)	5.0
Vanadium (V)	1.0
Zinc (Zn)	5.0

Table 2. Particle size distribution and total organic carbon in sediment samples collected from Wertheim National Wildlife Refuge in 1994

Sample No.	% Clay	% Sand	% Silt	% H_2O	TOC[1]	Type	Location
WT401	14.82	34	51.18	76.2	8.5	grab	BFC[2]
WT402	11.76	15.33	72.91	82.6	10	grab	BFC
WT403	17.22	16.34	66.44	83.1	9.4	grab	BFC
WT404	16.57	19.93	63.5	78.5	8.5	grab	BFC
WT405	8.25	21.62	70.13	81.9	9	grab	BFC
WT406	15.07	7.9	77.03	76.4	7.7	grab	BFC
WT407	5.77	71.14	23.09	91.5	30	grab	YC[3]
WT408	2.61	91.74	5.65	41	1.7	grab	YC
WT409	16.56	18.38	65.06	71.3	7.8	grab	YC
WT410	7.25	39.58	53.17	85	17	grab	YC
WT411	3.45	30.94	65.61	83	13	grab	CR[4]
WT412	18.21	17.25	64.54	76.4	10	grab	CR
WT413	10.46	18.38	71.16	73.3	5.9	grab	BAY[5]
WT414	0.58	93.05	6.37	40.8	0.98	grab	LNR[6]
WT415	7.42	77.72	14.86	67.6	5.6	grab	LNR
WT416	0.61	92.11	7.28	48.5	2.8	grab	LNR
WT417	2.69	56.99	40.32	87.9	20	grab	LNR
WT418	14.3	21.35	64.35	85.6	14	grab	LNR
WT419	3.31	83.44	13.25	81.2	17	grab	CR
WT420	1.87	71.93	26.2	65.7	6	grab	CR
WT421	0.32	99.04	0.64	28.2	1.6	grab	CR
WT422	1.03	92.3	6.67	39.4	5.1	grab	CR
WT423	4.99	55.13	39.88	79.2	23	grab	CR
WT424	0.43	98.7	0.87	30.9	0.54	grab	CR
WT425	0.32	99.36	0.32	34.3	13	grab	CR

Table 2. Continued							
Sample	Clay	Sand	Silt	% H_2O	TOC	Type	Location
WT426	38.09	29.27	32.64	89	38	grab	CR
WT427	14.22	25.32	60.46	83.2	13	grab	LFC[7]
WT428	3.37	59.6	37.03	70.2	13	grab	BFC
WT429	4.07	55.25	40.68	79.8	13	upper core	LNR
WT430	7.04	36.58	56.38	63.2	6.2	lower core	LNR
WT431	22.89	5.57	71.54	70.4	11	upper core	LNR
WT432	24.12	8.61	67.27	71.6	8.1	lower core	LNR
WT433	20.17	21.01	58.82	78.3	13	grab	YC
WT434	17.6	20	62.4	80.1	14	grab	YC
WT437	0.24	99.27	0.49	22.4	0.53	grab	YC
WT438	23.65	33.49	42.86	63.3	15	grab	UPL[8]
WT439	53.07	17.45	29.48	85	36	grab	UPL
WT440	7.78	86.66	5.56	3.5	0.86	grab	UPL
WT441	11.52	78.31	10.17	38.3	2.4	grab	UPL
WT442	10.88	81.86	7.26	5.3	0.69	grab	UPL
WT443	7.99	85.35	6.66	4.3	0.36	grab	UPL
WT454	17.61	35.95	48.44	78.7	17	grab	YC
WT455	24.73	25.83	49.44	89.2	18	grab	YC
WT456	10.79	19.09	70.12	88.5	21	grab	YC
WT457	9.95	25.37	64.68	86.1	24	grab	YC
WT457A	30.98	38.04	30.98	88	29	grab	YC
WT458	6.58	82.89	10.53	67.4	3.7	grab	LNR
WT459	5.34	87.79	6.87	57.3	3.4	grab	LNR

Table 2. Continued							
Sample	Clay	Sand	Silt	% H_2O	TOC	Type	Location
WT460	13.79	62.76	23.45	71.7	7.5	grab	LNR
WT460A	6.15	82.42	11.43	57.2	2.8	grab	LNR
WT461	30.05	28.63	41.32	82.8	43	grab	UCR
WT462	4.72	38.62	56.66	78.6	48	grab	CR
WT463	29.86	53.55	16.59	71.3	14	grab	CR
WT464	2.34	96.66	1	26.7	1.4	grab	CR
WT465	13.86	77.61	8.53	66.5	25	grab	LNR
WT466	3.51	89.07	7.42	9	1	grab	LNR
WT467	0.32	99.05	0.63	24.9	0.69	grab	LNR
WT468	1.73	91.78	6.49	4.5	0.98	grab	LNR
WT469	0.48	98.56	0.96	4.3	1.2	grab	UPL
WT470	0.51	96.96	2.53	11.3	0.34	grab	UPL
WT471	7.28	88.17	4.55	13.8	1.8	grab	UPL
WT472	5.22	94.31	0.47	33.6	0.63	grab	UPL

1. Total Organic Carbon, 2. Big Fish Creek, 3. Yaphank Creek, 4. Carman's River, 5. Bay
6. Little Neck Run, 7. Little Fish Creek, 8. Upland

Metal concentrations did not consistently correlate with percent sand, silt, clay, or total organic carbon content, although there was a positive correlation to silt and negative correlation to sand were frequent over all samples (Table 3). Big Fish Creek showed the greatest frequency of significant correlation (r = 0.754) between sediment sorting processes and metal concentrations, with higher concentrations generally associated with higher silt and lower sand contents. The lowest frequency of significant correlation (r = 0.482) was observed in the Carmans River samples. Some metals were consistently correlated with soil fractions, however. Chromium, magnesium, and nickel had a linear correlation with silt concentration in all locations; aluminum and vanadium were correlated with silt in all locations except Big Fish Creek. Boron and strontium were correlated with silt in all locations except Yaphank Creek. Nickel and vanadium were negatively correlated with sand in all locations. Aluminum was negatively correlated with sand everywhere except Carmans River. Magnesium was negatively correlated with sand everywhere except Yaphank Creek. Chromium was negatively correlated with sand in all stream locations, but not in the upland samples.

Total organic carbon (TOC) did not appear to be a consistent factor in the accumulation of most metals. Copper, lead, selenium, and strontium did have significant correlations to TOC levels, although not in all locations.

Figures 7-16 indicate the horizontal distribution of sediment metal concentrations on Wertheim NWR. The key to all of the figures is based on New York State Department of Environmental Conservation (NYSDEC) sediment criteria: the lowest range includes sample locations where metal concentrations were below the level of detection, the next range is from the level of detection up to the lowest biological effect level, the third range is from the lowest to the severe biological effect level, and the highest range includes samples with metal concentrations above the NYSDEC severe effect level.

Table 3. Statistically significant linear correlations between metal concentration and soil and sediment fractions in samples collected from Wertheim National Wildlife Refuge in 1994

	Upland	Big Fish Creek	Little Neck Run	Yaphank Creek	Carman's River	All
Al-clay	**	**				**
Al-sand	(**)	(*)	(**)	(**)		(**)
Al-silt	*		**	**	*	**
Al-TOC	**	*				
As-clay			*			*
As-sand	(**)	(*)	(**)			(**)
As-silt	**		**			**
As-TOC			*			
B-clay			**			*
B-sand		(**)	(**)		(*)	(**)
B-silt	**	**	**		**	**
B-TOC		*	*			
Ba-clay		*				
Ba-sand						
Ba-silt						
Ba-TOC						*
Be-clay	*	**				**
Be-sand		(**)		(**)		(**)
Be-silt		*		**		**
Be-TOC	*	*				
Cd-clay						
Cd-sand		(**)		(*)		(**)
Cd-silt		*		*		**

Table 3. Continued						
	Upland	Big Fish Creek	Little Neck Run	Yaphank Creek	Carman's River	All
Cd-TOC		*				
Cr-clay		*				*
Cr-sand		(*)	(**)	(**)	(*)	(**)
Cr-silt	**	*	**	**	*	**
Cr-TOC		*		*		
Cu-clay	**	*				**
Cu-sand	(**)	(**)		(*)		(**)
Cu-silt		*		**	*	*
Cu-TOC	**	*		*		*
Fe-clay		*	*			
Fe-sand		(**)	(**)	(**)		(**)
Fe-silt		*	**			**
Fe-TOC		*	*			
Hg-clay						
Hg-sand						(**)
Hg-silt		*				**
Hg-TOC						
Mg-clay						*
Mg-sand	(*)	(**)	(**)		(**)	(**)
Mg-silt	**	*	**	**	**	**
Mg-TOC			*			
Mn-clay		*				
Mn-sand		(**)				
Mn-silt		**	*			
Mn-TOC		**				

Table 3. Continued						
	Upland	Big Fish Creek	Little Neck Run	Yaphank Creek	Carman's River	All
Mo-clay					**	*
Mo-sand					(**)	(**)
Mo-silt						**
Mo-TOC					*	
Ni-clay	**	*				**
Ni-sand	(**)	(**)	(**)	(**)	(**)	(**)
Ni-silt	**	*	**	**	**	**
Ni-TOC	**	*				
Pb-clay	**					*
Pb-sand	(**)					(*)
Pb-silt	*					
Pb-TOC	**		**	**		**
Se-clay						**
Se-sand						(*)
Se-silt						
Se-TOC				**	**	**
Sr-clay					*	**
Sr-sand	(**)	(*)	(**)		(**)	(**)
Sr-silt	**	*	**		*	**
Sr-TOC	*		**	**	**	**
V-clay		*	**			**
V-sand	(*)	(*)	(**)	(**)	(**)	(**)
V-silt	**		**	**	**	**
V-TOC		(*)	**			
Zn-clay		*				

Table 3. Continued						
	Upland	Big Fish Creek	Little Neck Run	Yaphank Creek	Carmans River	All
Zn-sand		(**)		(*)		(**)
Zn-silt		*				**
Zn-TOC		(**)				
Total correlations	28	47	30	22	20	50

* = P < 0.05 ** = P < 0.01 () = negative correlation

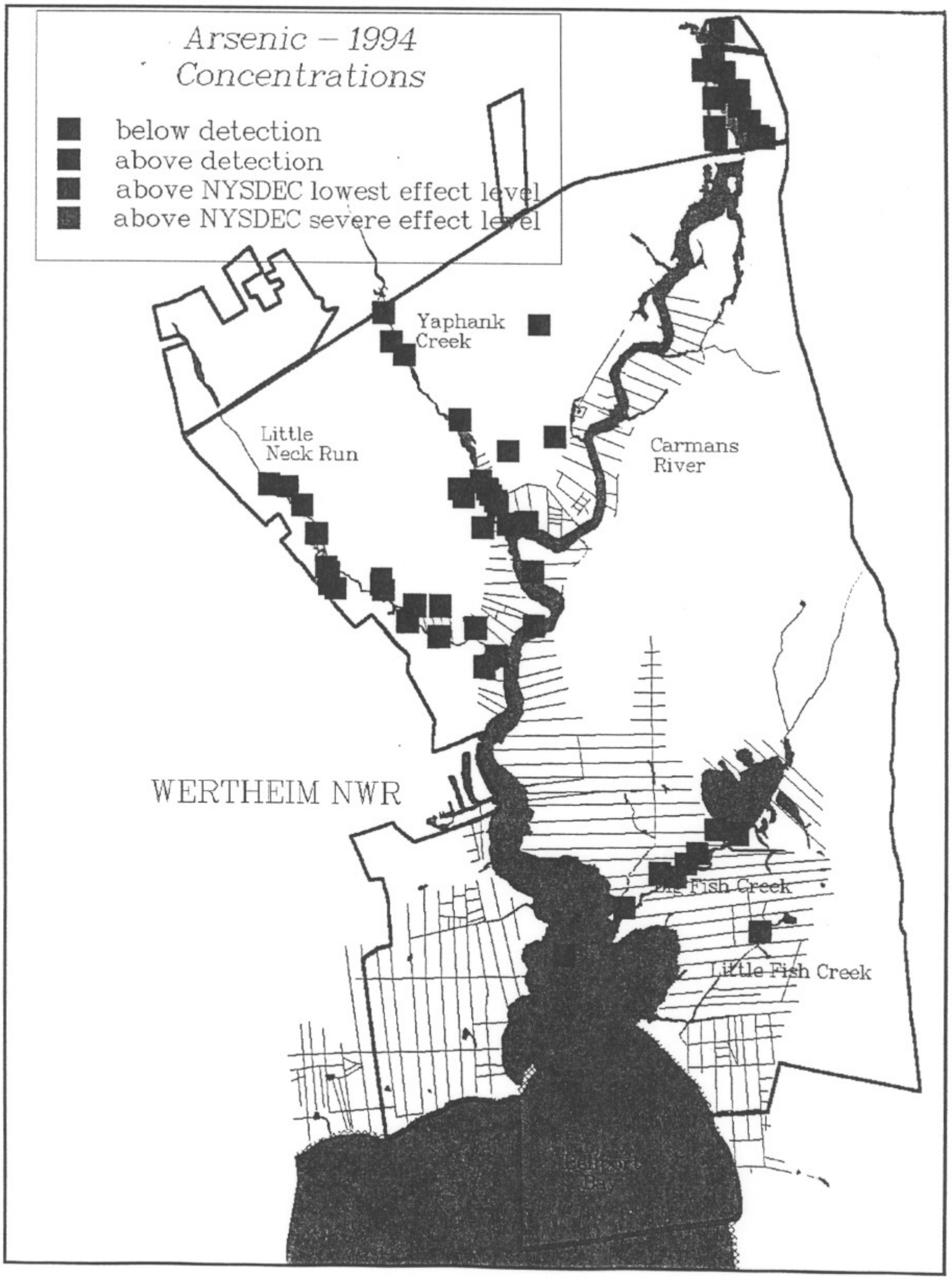

Figure 7. Arsenic distribution at Wertheim National Wildlife Refuge, 1994

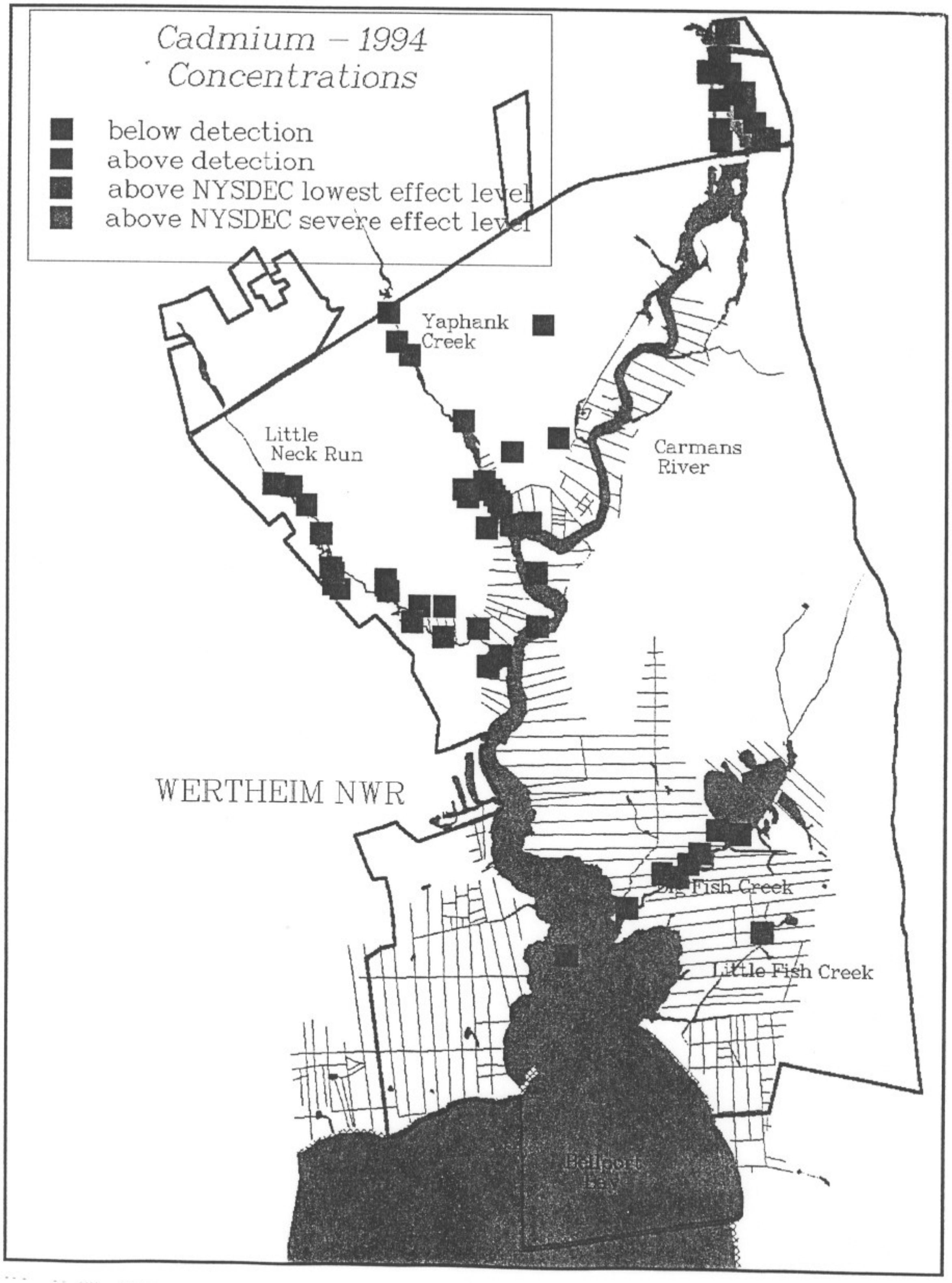

Figure 8. Cadmium distribution at Wertheim National Wildlife Refuge, 1994

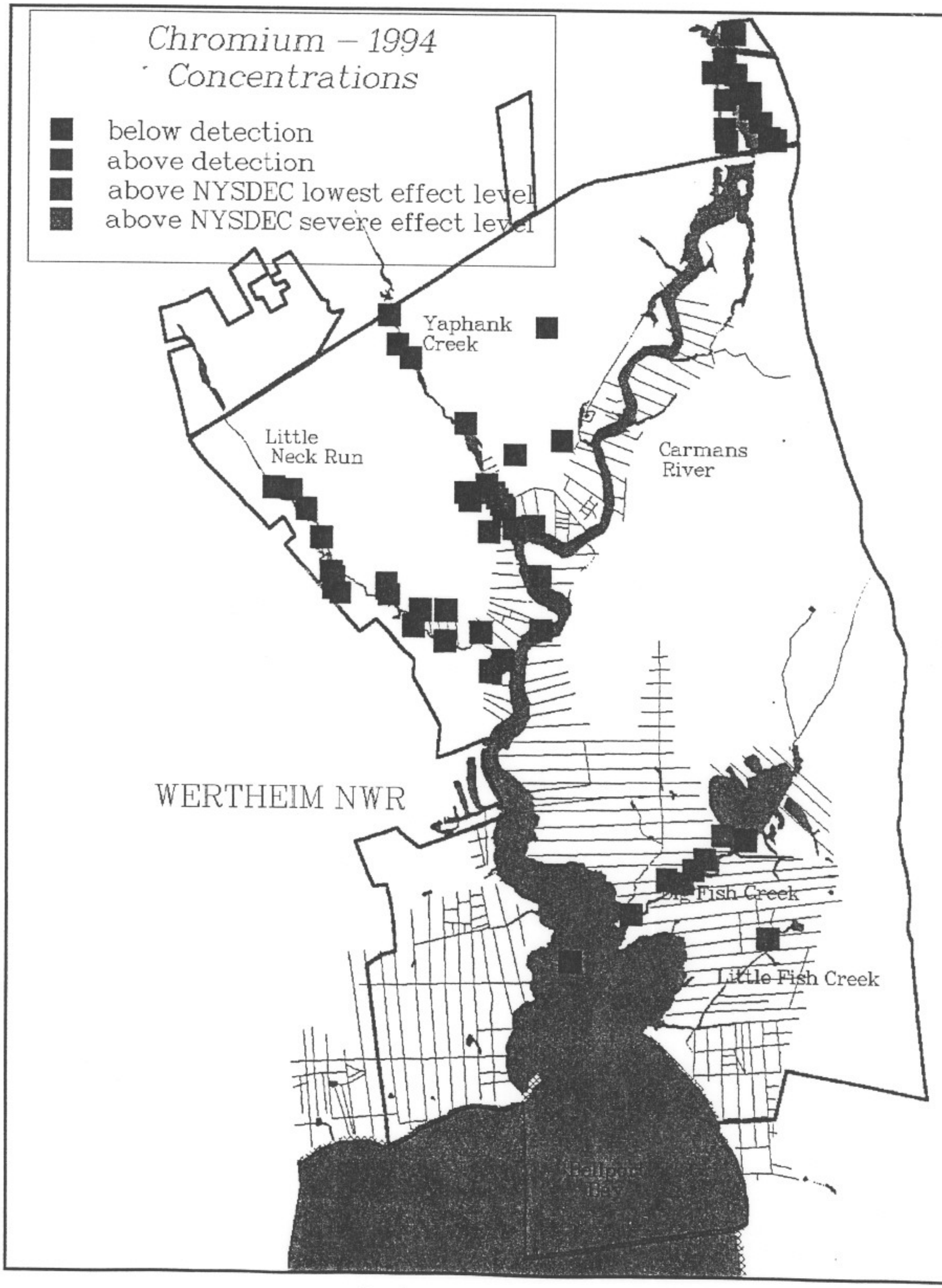

Figure 9. Chromium distribution at Wertheim National Wildlife Refuge, 1994

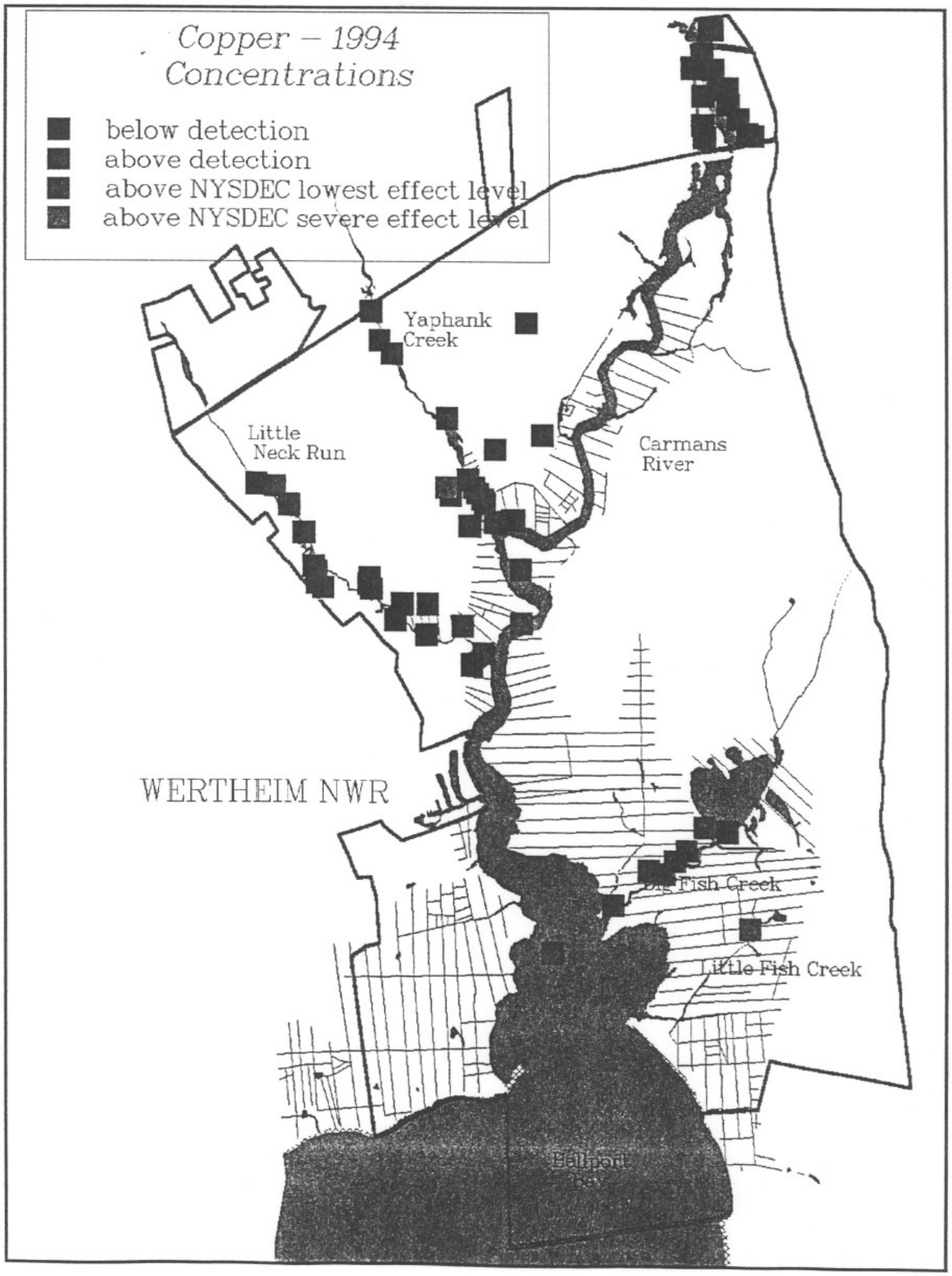

Figure 10. Copper distribution at Wertheim National Wildlife Refuge, 1994

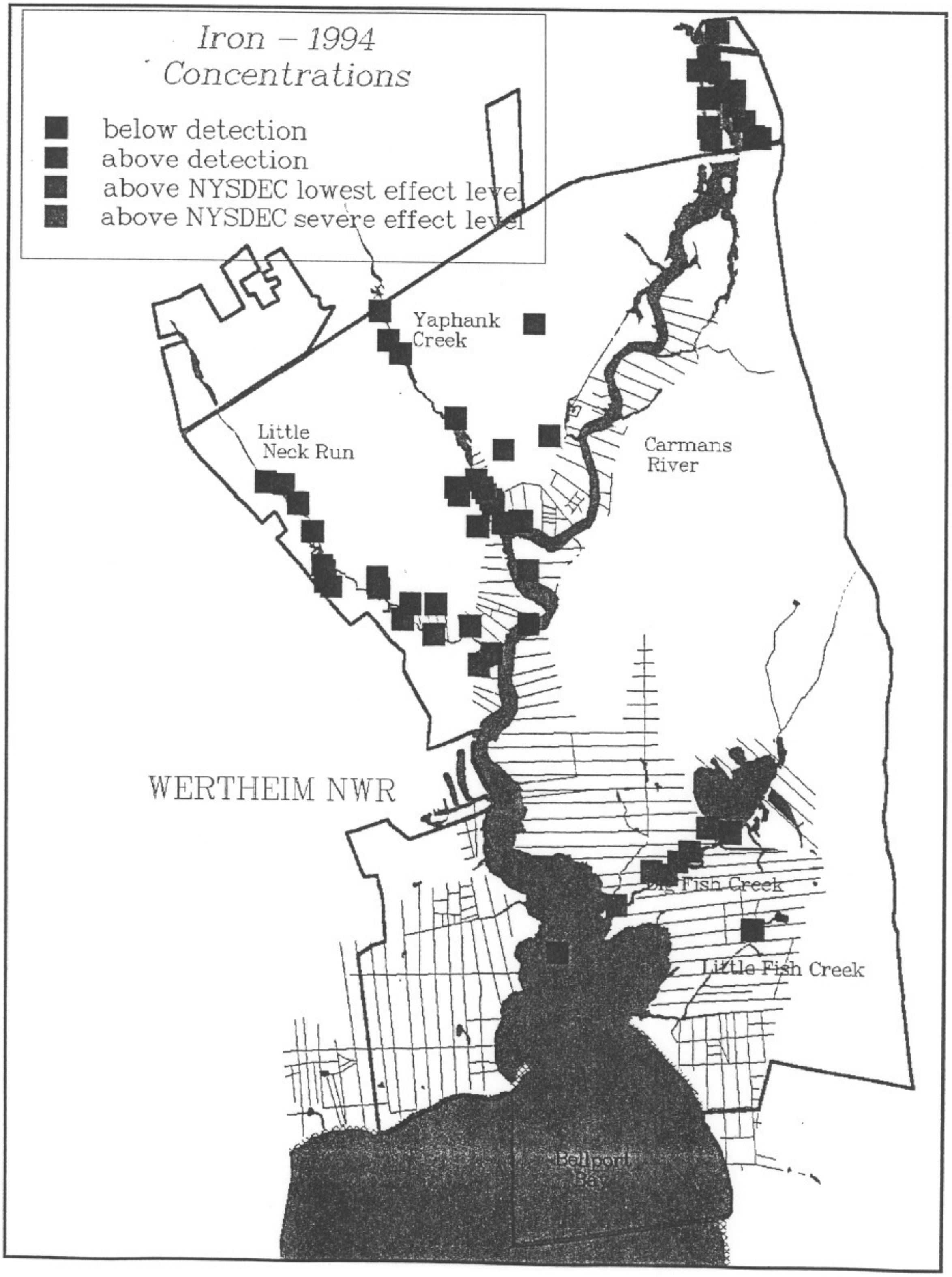

Figure 11. Iron distribution at Wertheim National Wildlife Refuge, 1994

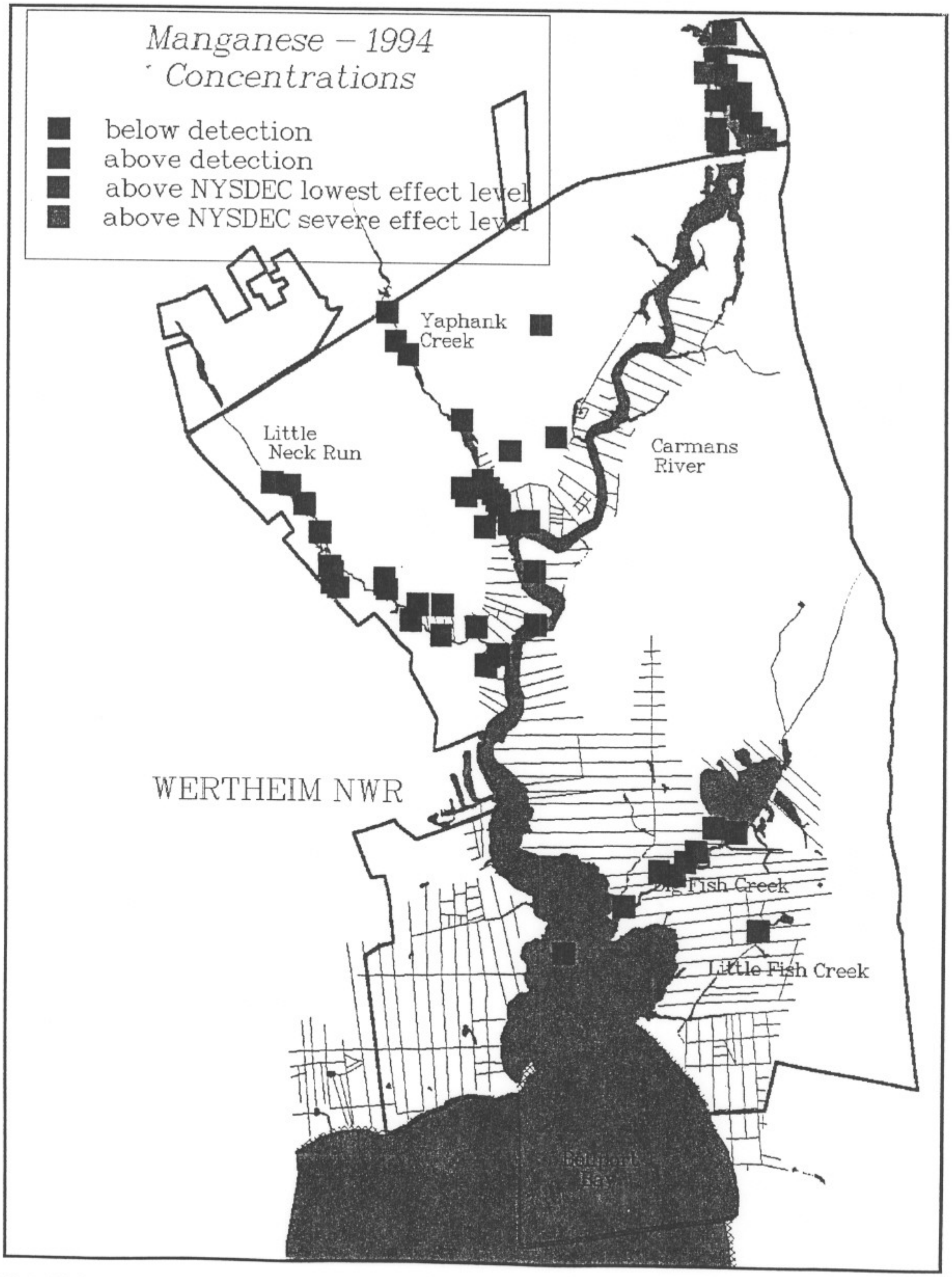

Figure 12. Manganese distribution at Wertheim National Wildlife Refuge, 1994

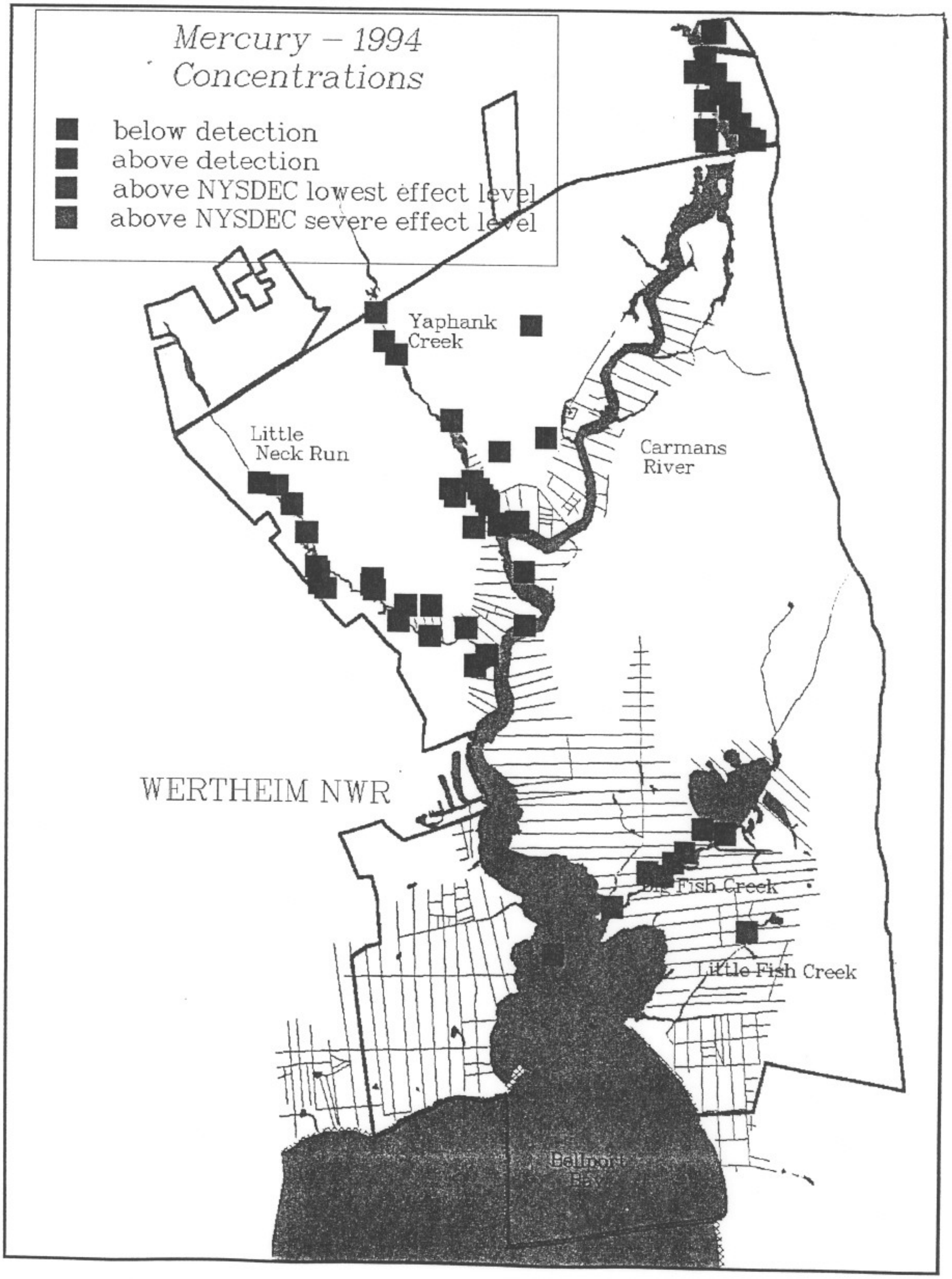

Figure 13. Mercury distribution at Wertheim National Wildlife Refuge, 1994

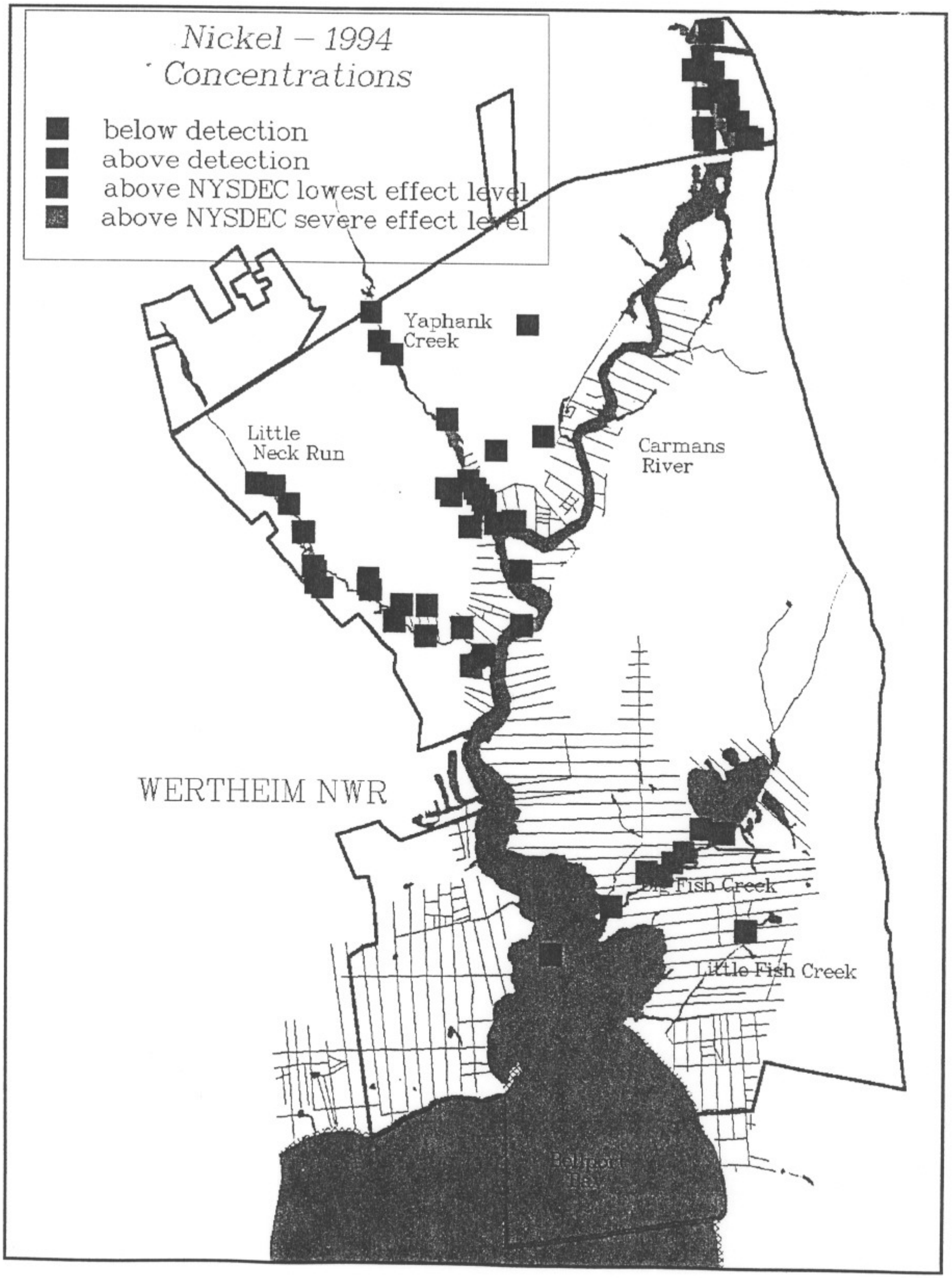

Figure 14. Nickel distribution at Wertheim National Wildlife Refuge, 1994

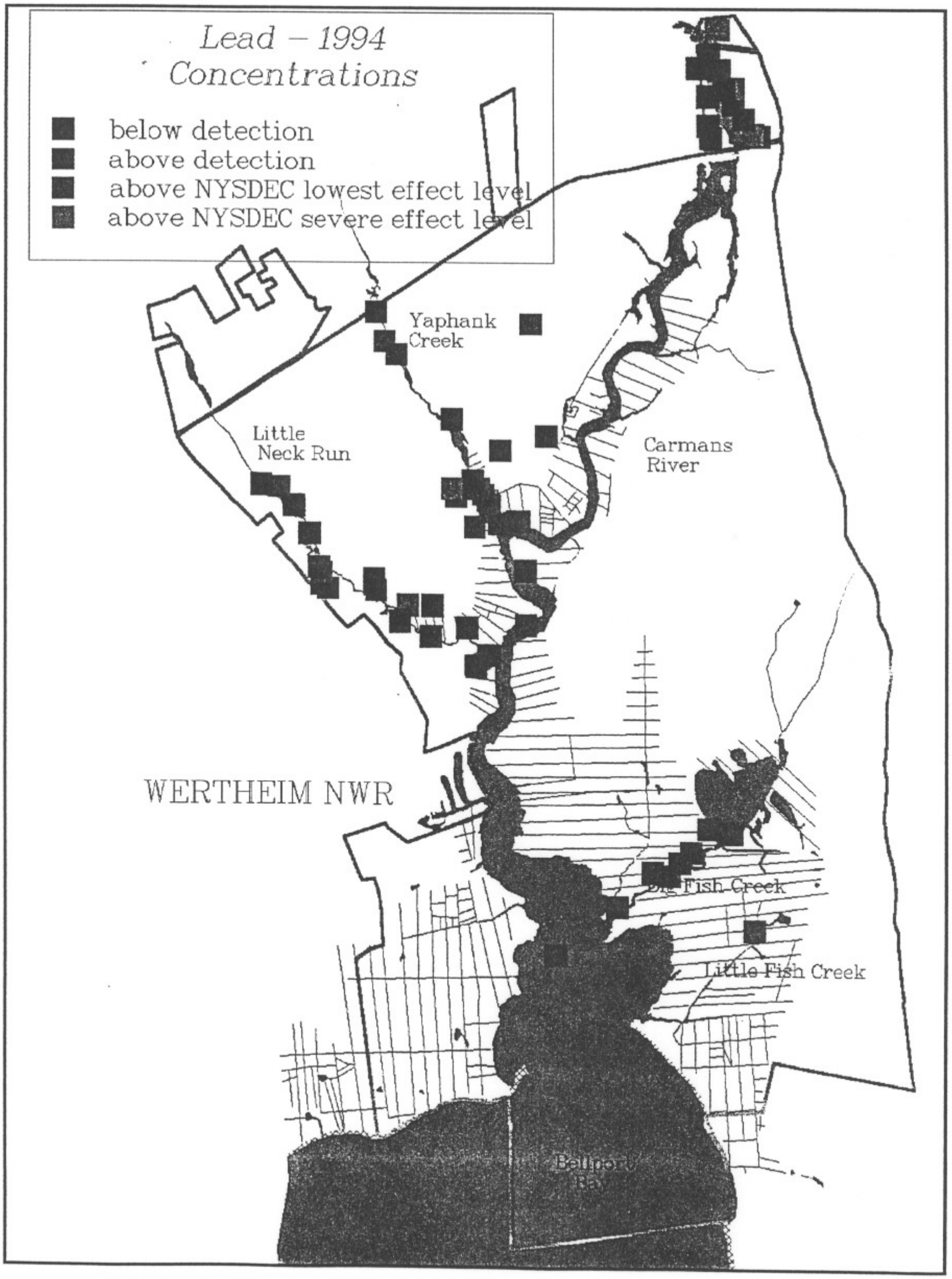

Figure 15. Lead distribution at Wertheim National Wildlife Refuge, 1994

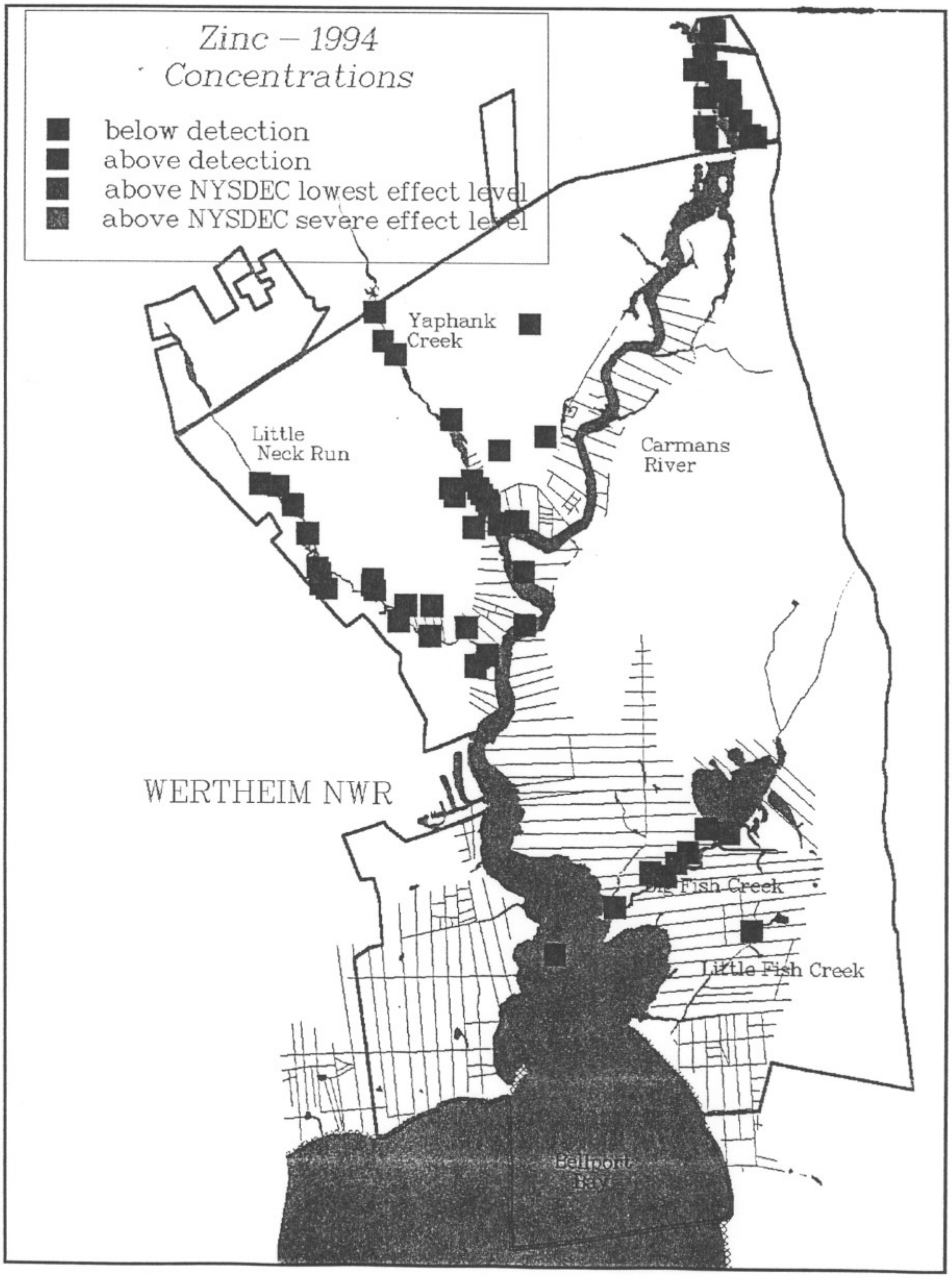

Figure 16. Zinc distribution at Wertheim National Wildlife Refuge, 1994

Sediments of the Upper Carmans River, the mouths of Yaphank Creek and Little Neck Run, and the full length of Big Fish Creek routinely contained concentrations of toxic elements above the lowest biological effect level, and occasionally above the severe effect level, for elements where sediment criteria are available. Only lead and manganese concentrations exceeded the NYSDEC severe effect level. Although one copper sample also exceeded the NYSDEC severe effect concentration, it came from an upland soil sample; the NYSDEC guidelines are for aquatic sediments. Of all sites sampled, it appears that only the head of Little Neck Run and the upland locations are consistently below the biological effect level for most of the elements tested; however, high concentrations were occasionally observed at these points as well.

The Carmans River had the maximum observed concentrations of arsenic, boron, barium, beryllium, cadmium, chromium, iron, manganese, molybdenum, lead, and strontium. Surprisingly, samples taken from the western bank of the Upper Carmans River had some of the lowest concentrations of metals, while samples taken from the east bank had some of the highest. The River is narrow at this point, and the sample points are so close together that any contaminant source affecting one point would be expected to have a similar impact on other points nearby, at least forming a gradient from points of high concentration to points of low concentration. However, the results seem to indicate relatively confined contaminant hot spots in this area.

Big Fish Creek had the maximum observed concentrations of mercury, magnesium, nickel, and vanadium. Little Neck Run had the maximum observed concentrations of aluminum and zinc, while the maximum observed concentrations of copper and strontium were found in upland areas.

The most contaminated single location was sample point WT 420, located just north of Montauk Highway on the east side of the Carmans River, which had the maximum observed concentrations of five elements, including arsenic, barium, cadmium, chromium, and manganese. The concentration of lead at this point, though not the maximum observed, was also above the NYSDEC severe effect level.

Fish Tissue collected at Wertheim NWR

Fish tissue samples were not correlated to metal concentrations in the nearest sediment sample. Beryllium and molybdenum were not detected in any tissue samples, cadmium was detected in only one sample, and nickel and lead were only detected in two samples. The detections of cadmium, nickel, and lead were all near the limit of detection. Maximum fish tissue concentrations were distributed among several samples, with no one sample showing an exceptional degree of contamination. However, the fact that not all samples were of the same species of fish makes comparison among samples uncertain. Sample 436 (killifish, Yaphank Creek) had the highest level of vanadium (1.5 μg/g) (Table 4). Sample 444 (killifish, mouth of Yaphank Creek) had the highest levels of arsenic (3.21 μg/g), boron (5.2 μg/g), barium (13.8 μg/g), and strontium (380.5 μg/g) (Table 4). Sample 446 (Atlantic silverside, mouth of Big Fish Creek) had the highest levels of aluminum (154.3 μg/g), magnesium (2001 μg/g), and zinc (139.7 μg/g) (Table 4). Sample 447 (Atlantic silverside, mouth of Little Fish Creek) had the highest selenium (1.82 μg/g) concentration (Table 4). Sample 451 (killifish, upper Carmans River) had the highest level of manganese (114.9 μg/g) (Table 4). Sample 452 (killifish, mid Carmans River) had the highest levels of chromium (9.2 μg/g) and copper (13.5 μg/g) (Table 4). Sample 453 (killifish, the impoundment at Big Fish Creek) had the highest levels of iron (354.1 μg/g) and mercury (0.457 μg/g) (Table 4).

DISCUSSION

Various concern levels will be referred to in this discussion to evaluate the concentrations of contaminants found in this study. These concern levels will include the apparent effects threshold (AET) for contaminants in sediment from Puget Sound (Barrick et al. 1988), the National Oceanic and Atmospheric Administration's (NOAA) biological

Table 4. Metal concentrations (ppm, wet weight) in fish tissue samples collected from Wertheim National Wildlife Refuge in 1994

Sample	Species	% H_2O	Al	As	B	Ba	Be	Cd	Cr	Cu
WT435	killifish	74.1	50.2	0.56	<2	3.9	<.1	<.1	1.8	3.7
WT436	killifish	77.6	72.2	2.73	<2	9.2	<.1	<.1	3.2	4.8
WT444	killifish	77.8	33.6	*3.21	*5.2	*13.8	<.1	<.1	5.3	4.8
WT445	killifish	78.1	73.5	1.68	2	11.4	<.1	<.1	6.7	10.1
WT446	silverside	78.2	*154.3	1.26	3.1	8.9	<.1	<.1	5.1	4.5
WT447	silverside	78.5	80.6	0.78	2.6	5.1	<.1	<.1	3.4	3
WT448	silverside	76.4	13.7	0.74	3.5	5.7	<.1	<.1	3.3	2.5
WT449	silverside	78.2	24.2	<.5	<2	6.9	<.1	<.1	4.2	2.8
WT450	eel	77	56.8	<.5	<2	10.9	<.1	<.1	6.2	10.4
WT451	killifish	78.1	54.2	<.5	<2	12.7	<.1	*0.11	7.8	10.2
WT452	killifish	75.6	64.5	<.5	3	11.8	<.1	<.1	*9.2	*13.5
WT453	killifish	77.1	66.9	<.5	<2	9.3	<.1	<.1	5	7.5

Table 4 (continued)

Sample	Species	Fe	Hg	Mg	Mn	Mo	Ni	Pb	Se	Sr
WT435	killifish	117.5	0.182	1310.7	1.4	<2	<.5	<.5	1.55	127.1
WT436	killifish	127.4	0.219	1864.2	44	<2	<.5	<.5	0.87	324.5
WT444	killifish	90.5	0.296	1995.4	58.6	<2	<.5	<.5	<.5	*380.5
WT445	killifish	152.4	0.251	1752.9	65.4	<2	<.5	<.5	1.03	296.3
WT446	silverside	228.2	0.143	*2001	34.2	<2	<.5	<.5	1.07	245.5
WT447	silverside	129.4	0.111	1749.8	38.1	<2	<.5	<.5	*1.82	164.8
WT448	silverside	40.7	0.140	1899.4	41.1	<2	<.5	<.5	1.61	212.2
WT449	silverside	73.4	0.237	1664.2	24.9	<2	<.5	<.5	1.70	194.1
WT450	eel	180.1	0.183	1698.3	91.9	<2	<.5	<.5	1.12	265.0
WT451	killifish	218.2	0.139	1599.1	*114.9	<2	*1	*0.57	1.51	141.3
WT452	killifish	126.2	0.232	1930.2	57.9	<2	*1	<.5	1.33	321.4
WT453	killifish	*354.1	*0.457	1687.2	76.6	<2	<.5	0.54	1.16	298.6

Table 4 (continued)

Sample	Species	V	Zn
WT435	killifish	1.1	81.4
WT436	killifish	*1.5	133.4
WT444	killifish	0.8	138.1
WT445	killifish	0.9	125.6
WT446	silverside	1.3	*139.7
WT447	silverside	1	128.4
WT448	silverside	1	135.9
WT449	silverside	1.1	138.3
WT450	eel	1.3	133.4
WT451	killifish	1.2	132.4
WT452	killifish	0.7	127.4
WT453	killifish	1	122.57

* = maximum observed concentration

effect levels (Long and Morgan 1990), New York State Department of Environmental Conservation's (NYSDEC) sediment guidelines for the Division of Fish and Wildlife (NYSDEC 1993), the International Joint Commission's (IJC) suggested background sediment concentrations for the Great Lakes (Ingersoll and Nelson 1989), inorganic compound concentrations typically found in Long Island soil (Cappelli, pers. comm.), elemental concentrations in surficial materials (Shacklett et al. 1971), and various predator protection levels.

The proportions of sand, silt, and clay observed in samples collected from the Carmans River and the other creeks in its watershed suggest that typical sorting processes are observed. Sediment texture is often controlled by stream velocity, which is highest at the headwaters and decreases at the mouth. Where stream velocities are high, small particles are suspended and removed. As stream velocity slows, small particles may be deposited on the stream bed. The results is that sediments in stream head waters are generally coarser (more sand) while finer sediments (silt and clay) will accumulate near the stream mouth. In this set of samples, the removal and accumulation process follows this typical scenario. In Big Fish Creek, Little Neck Run, and Carmans River, downstream accumulation of fines conforms to a linear model ($P < 0.05$), but Yaphank Creek does not. However, it is clear that the percentage of silt rises while the percentage of sand falls downstream in Yaphank Creek, even though the rate of change is not linear.

The greater surface area of fine sediments is expected to result in their greater accumulation of contaminants of all kinds, including metals. As noted in the results section, this relationship is not consistently observed in the Wertheim NWR waterways. In the Carmans River, and possibly in Yaphank Creek, metal concentrations at a given site may reflect the greater importance of proximity to contaminant sources (e.g., Montauk Highway and the Long Island Rail Road track) when compared to natural distribution forces.

The cause of the consistently high levels of metals in Big Fish Creek, which is not close to an obvious contaminant source, is not known. The distribution of metals in Big Fish Creek is more closely correlated to accumulations of fine materials than in any other Wertheim NWR stream. This suggests that Big Fish Creek is influenced by a non-point source of contaminants, as the distribution of contaminants appears to relate more to natural sorting processes and less to geographical position. Because Big Fish Creek lies entirely within the tidal reach of Bellport Bay, it is likely that the source of contaminants found in Big Fish Creek is Bellport Bay, rather than runoff from upland areas. However, come contaminants are found in higher concentrations in Big Fish Creek than in the Bay, suggesting that an additional concentration process occurs in the Creek sediments.

Bioaccumulation of a given substance is expected to reflect the levels of that substance in a given organism from all routes of exposure. No relationship was observed between sediment metals levels and metals levels in fish. However, the species sampled are not bottom feeders, so their connection to sediment chemistry is less direct than would be expected for a bottom-feeder. The uptake of sediment metals to water column species is uncertain. Likewise, the impact of contaminated sediments on all the biota of Wertheim NWR is unknown at present.

Sediment collected from Wertheim NWR in 1994 had levels of lead, mercury, zinc, copper, arsenic, cadmium, chromium, nickel, iron, and manganese exceeding at least one of the concern levels reviewed. Sediment samples from Wertheim in 1990 and 1991 indicated that the same inorganic residues were found to exceed the concern levels (Mann and Karwowski 1991, Mann-Klager and Parris 1993). While much of the contamination due to inorganics is confined to particular areas of the refuge, concentrations of cadmium and lead exceeding the NYSDEC lowest biological effects level are found throughout Wertheim NWR.

Arsenic is listed by the U.S. Environmental Protection Agency (USEPA) as one of 129 priority pollutants (Keith and Telliard 1979). It is a nonmetallic element which has long been a concern because small amounts are toxic to humans (Hem 1985). Arsenic enters rivers from air pollution (fossil fuel combustion) and soil erosion as well as from pesticides and industrial sources. Significant amounts of arsenic are known to leach from municipal landfills (Health and Environment Network 1987). Arsenic is produced as a by-product of zinc, copper, and lead smelters, and also through the large-scale burning of coal (Green 1988). Arsenic is used in a wide range of alloys, medicines, and electronic devices (National Library of Medicine 1988). The potential for bioaccumulation and bioconcentration is high to very high for mollusks, crustacea, lower animals, and higher plants (Jenkins 1981). Sediment concentrations ranged from <0.5 μg/g to 27.69 μg/g. The NYSDEC 1993 guidelines describe 6 μg/g as the lowest effect level and 33.0 μg/g as the severe effect level. Out of 72 samples, all but 6 exceeded the Great Lakes background levels of 1.1 μg/g (Ingersoll and Nelson 1989). All of the sediment samples collected on Big Fish Creek in 1994 had levels of arsenic greater than both the NYSDEC concern level and the Great Lakes background sediment level (Figure 7).

Cadmium is a relatively rare, soft, silver-white, transition metal which is listed by the USEPA as one of 129 priority pollutants (Keith and Telliard 1979). All cadmium compounds are potentially harmful or toxic (Jenkins 1981). Cadmium is very toxic to a variety of species of fish and wildlife. It causes behavior, growth, and physiological problems in aquatic life at sublethal concentrations (Rompala et al. 1984). Cadmium tends to bioaccumulate in fish, clams, and algae, especially in species living in close proximity to sediments contaminated by cadmium (Rompala et al. 1984, Munawar et al. 1984, Schmitt et al. 1987). It is a suspected carcinogen and has been shown to cause birth defects in mammals (Ames et al. 1987, Friberg et al. 1979). Mammals and birds consuming cadmium-contaminated food experienced lowered sperm counts, kidney damage, increased mortality of young, elevated blood sugar, and anemia (Rompala et al. 1984). About 75% of all cadmium produced is used for cadmium plating of easily corroded metals such as iron and steel. Because of its low melting point (21.09°C), it is used in special alloys such as aluminum solder, and related alloys that are used for sprinkler installations and other fireprotection systems (Grolier Electronic Publishing 1988). Other sources of cadmium include: smelters, incinerators, oil furnaces, coal combustion, metal platers, scrap yards, batteries, television tubes, solar cells, fungicides, and various industrial discharges (Rompala et al. 1984). Significant amounts of cadmium can also be found in sewage sludge and in leachate from municipal landfills (Friberg et al. 1979, USEPA 1983, Health and Environment Network 1987, Lu et al. 1982). The potential for bioaccumulation or bioconcentration is high for the following biota: mammals, birds, fish, mosses, lichens, algae, mollusks, crustacea, lower animals, and higher plants (Jenkins 1981). The range of cadmium concentrations was from < 0.2 to 4.42 μg/g in Werthein NWR sediments and soils. The NYSDEC lowest effect level for cadmium is 0.6 μg/g (NYSDEC 1993). The suggested Great Lakes background sediment concentrations of cadmium is also 0.6 μg/g (Ingersoll and Nelson 1989). Concentrations in excess of 0.6 μg/g were found in samples taken throughout the refuge (Figure 8).

Chromium is a metallic element which is listed by the USEPA as one of 129 priority pollutants (Keith and Telliard 1979). Chromium does not occur free in nature; in bound form it makes up 0.1-0.3 parts per million on the Earth's crust (Grolier Electronic Publishing 1988). Although some salts of it are carcinogenic, and specific chromium compounds are quite toxic, the element itself has moderate to low toxicity (Jenkins 1981). Known sources of chromium include metal platers and a wide variety of chemical, photography, metal plating, scrap metal, machine shop, power plant, and industrial facilities (Eisler 1988, Rompala et al. 1984). Chromium is also present in the leachate of some municipal landfills (Lu et al. 1982). The potential for bioaccumulation is considered high to very high for mosses, lichens, algae, mollusks, crustacea, lower animals, and higher plants (Jenkins 1981). The concentration of chromium ranged in sediments and soils from Wertheim NWR from < 1 to 49.1 μg/g, greater than the NYSDEC lowest biological effect guideline of 26 μg/g (NYSDEC 1993). Several samples had a concentration of chromium that exceeded the Great Lakes background level as determined by the IJC (37.1 μg/g) (Ingersoll and Nelson 1989). Chromium concentrations were particularly high on Big Fish Creek and Yaphank Creek (Figure 9).

Copper is listed by the USEPA as one of 129 priority pollutants (Keith and Telliard 1979). Copper is widely distributed in nature in the elemental state, in sulfides, arsenites, chlorides, and carbonates (National Library of Medicine 1988). Copper was the first metal used by man and is second only to iron in its utility through the ages. There are more than 1,000 alloys which incorporate copper. Copper is one of the most common contaminants associated with urban runoff, and specific sources include soil erosion, corrosion of pipes and tubes, industrial discharges, and sewage outfalls (USEPA 1980a). Minute amounts of copper are needed in the diet of humans, plants, and animals for enzyme production. Ingestion of copper in excess of dietary requirements leads to accumulation in tissues, particularly the liver and kidneys, which can cause copper toxicosis and cell damage (Leland and Kuwabara 1985). The potential for bioaccumulation of copper is high to very high for the following biota: mammals, birds, fish, mosses, lichens, algae, mollusks, crustacea, lower animals, and higher plants (Jenkins 1981). The soil and sediment concentrations of copper at Wertheim NWR generally ranged from 1 μg/g to 34.5 μg/g, with one upland soil point, WT 439, having a concentration of 155.1 μg/g. The concentration of copper in several samples was greater than the level considered by the IJC as the Great Lakes background (21.1 μg/g) (Ingersoll and Nelson 1989), and greater than the NYSDEC 1993 lowest effect level of 19 μg/g. Because WT 439 is an upland soil point, rather than an aquatic sediment, the ecological implications of its high concentration of copper are uncertain. No established criteria exist for upland soils. The distribution of copper is shown in Figure 10.

Manganese occurs in nature in various salts and oxides and it is used in various industrial and agricultural applications. In localities where it is elevated, manganese is an important freshwater quality ion which contributes to water "hardness." Manganese is a required trace element for both plants and animals (USEPA 1986). Fish have some ability to excrete excess manganese, but the precise significance of excess body burdens is unclear for most species of fish and wildlife. Manganese tends to accumulate in bone, skin, and scales (Schmitt et al. 1987). Manganese is thought to be less of a toxicity problem in natural waters than many of the other contaminants typically analyzed in inorganic contaminant profile scans (National Academy of Sciences 1973). Pure manganese is rarely used, as it is a moderately reactive and brittle metal (Fleishman 1988). It occurs naturally in surface waters from soil erosion. Other sources include air pollution deposition from power plants, sewage treatment plant effluents, and leachates from municipal landfills (Lu et al. 1982). About 95% of the world's annual production of manganese is used by the iron and steel industry. In alloys, it increases the durability and corrosion resistance of iron and steel and makes steel more malleable when forged. Manganese alloys are used in grinding machinery, wrecking equipment, and mechanical pounding equipment used in heavy-duty construction (Fleishman 1988). Only NYSDEC has developed a concern level found for this element, with a lowest effect level of 460 μg/g and a severe effect level of 1100 μg/g (NYSDEC 1993). Sample concentrations ranged from to 24.5 to 4688 μg/g at the Wertheim NWR; four samples, WT 20, WT 426, WT 461, and WT 462, all in the northeastern corner of the refuge, exceeded the NYSDEC severe effect level (Figure 12).

Mercury is listed by the USEPA as one of 129 priority pollutants (Keith and Telliard 1979). Mercury has a melting point of 3.33°C which makes it the only metallic element that is liquid at room temperature, and its volatility tends to reduce its concentration in surface water (Schmitt et al. 1987). It is one of the few metals which strongly bioconcentrates and biomagnifies, and has only harmful effects with no useful physiological functions when present in fish and wildlife. Mercury is a carcinogen, mutagen, and teratogen; and is easily transformed from a less toxic inorganic form to a more toxic organic form in fish and wildlife tissues (Eisler 1987). When exposed to mercury in both media, fish accumulate more mercury from sediments than from water (Munawar et al. 1984). Plants take up mercury from soil, ground water, sewage sludge, biocides, fertilizers, and air pollution. Animals accumulate mercury from industrial sources, contaminated water, and contaminated food (Jenkins 1981). Sources of mercury include batteries, vapor discharge lamps, thermometers, older-style seals in sewage treatment plants, sewage treatment plant discharges, the chloralkali industry, paints, pesticide compounds, switches, valves, dental labs and offices, pharmaceuticals, scientific and analytical laboratories, soil erosion, and air pollution deposition from fossil fuel combustion and smelters (Eisler 1987). Leachates of municipal landfills contain mercury (Lu et al. 1982). The mercury concentration at Wertheim NWR ranged from <0.1 to 0.22 μg/g, which was greater than the lowest potential for biological effects of this contaminant sorbed to sediments suggested by the NOAA (0.15 μg/g) (Long and Morgan 1990). In samples above the detection limit (0.1 μg/g), mercury was detected at levels which were greater than the concentration which is considered by the IJC to be background for Great Lakes sediments (0.03 μg/g) (Ingersoll and Nelson 1989). All sample locations on Big Fish Creek in 1994 exceeded both the NOAA and NYSDEC concern levels (Figure 13).

Nickel is listed by the EPA as one of 129 priority pollutants (Keith and Telliard 1979). Little information is available on the effects of nickel body burdens on fish and wildlife, but experimental doses of nickel have induced cancer in rats, guinea pigs, and rabbits (USEPA 1980b). Mixtures of nickel, copper, and zinc produced additive toxicity effects on rainbow trout *(Oncorhynchus mykiss)* (Rompala et al. 1984). The potential for bioaccumulation of nickel appears to be high to very high for mollusks, crustacea, lower animals, mosses, lichens, algae, and higher plants (Jenkins 1981). Concentrations of nickel ranged from <5 to 19.5 μg/g. NOAA determined that the potential for biological effects was highest in sediments where its concentration exceeded 50 μg/g and was lowest in sediments where its concentration was less than 30 μg/g (Long and Morgan 1990). The IJC suggested sediment concentrations not exceed background levels of 32.3 μg/g (Ingersoll and Nelson 1989). The concentration proposed by NYSDEC as the lowest biological effect level is 16 μg/g, with a severe effect level of 50 μg/g (NYSDEC 1993). Nickel distribution is reported in Figure 14.

Lead is listed by the U.S. Environmental Protection Agency (USEPA) as one of 129 priority pollutants (Keith and Telliard 1979). Lead is a heavy metal which is very toxic to aquatic organisms, especially fish (Rompala et al. 1984). Benthic fish may accumulate lead directly from the sediments (Munawar et al. 1984). Lead also tends to bioaccumulate in mussels and clams (Schmitt et al. 1987, Munawar et al. 1984). All measured effects of lead on living organisms are adverse, including those negatively affecting survival, growth, learning, reproduction, development, behavior, and metabolism (Eisler 1988). Effects of sublethal concentrations of lead include mucous formation, delayed embryonic development, suppressed reproduction, inhibition of growth, and fin erosion (Rompala et al. 1984). In vertebrates, sublethal lead poisoning is characterized by neurological problems (including blockage of acetylcholine release), kidney dysfunction, enzyme inhibition, and anemia (Leland and Kuwabara 1985). In birds, lead has also been implicated in decreases in eggshell thickness, growth, ovulation, and sperm formation (Rompala et al. 1984). Typical sources of lead include atmospheric fallout from motor vehicle and smelter emissions as well as sewage sludge, batteries, pipes, glazes, paints, and alloys. The lead burdens in sediments in this study ranged from $<$ 5 to 243.2 μg/g, with samples WT 419, WT 420, WT 423, WT 426, WT 439, WT457, and WT 465 exceeding the potential for severe biological effects of this contaminant sorbed to sediment as reported by the NOAA (110.0 μg/g) (Long and Morgan 1990) and NYSDEC (1993). The level considered by the IJC to be background for Great Lakes sediment (27.5 μg/g) (Ingersoll and Nelson 1989) was also exceeded in many locations. Lead levels in sediment samples collected in 1994 from all areas in Wertheim NWR consistently exceeded both the NOAA lowest biological effect level (Long and Morgan 1990) and the NYSDEC (1993) concern level (Figure 15).

Zinc is listed by the USEPA as one of 129 priority pollutants (Keith and Telliard 1979). It is widely distributed in nature, making up between 0.0005% and 0.02% of the Earth's crust. Zinc is an essential element for plant and animal life (Keller 1988). However, there have been cases of excessive amounts of zinc causing poisoning in humans as well as fish and wildlife. Zinc is one of the most common contaminants associated with urban runoff. Other sources include soil erosion, industrial discharges, pharmaceuticals, and pesticides (USEPA 1980a). Zinc concentrations ranged from < 5 to 169.5 μg/g, greater than the lowest potential for biological effects as suggested by the NOAA and NYSDEC (120 μg/g). However, only four locations exceeded the 120 μg/g level (Figure 16). The IJC criterion for Great Lakes background sediment concentrations of 120 μg/g was exceeded as well (Ingersoll and Nelson 1989).

The Carmans River has a drainage of 71 mile^2. Traversing this drainage are two major highways, Sunrise and Montauk, and the southern extension of the Long Island Railroad. It has been hypothesized that the use of leaded lures, split shot, and sinkers in fishing may contribute to the elevated lead levels found at some points in the river. However, the figures in this study indicate that high lead levels are associated with high levels of other metals, suggesting a common source for several elements. One possible common source is urban, highway, and railway runoff. Lead, zinc, and cadmium are all components of tire material, while copper and chromium are found in brake linings (USEPA 1991). As discussed above, copper, iron, and zinc are common components in urban runoff due to their widespread use in metal objects of all kinds. Another possible source of contaminants to Wertheim NWR is the deposition of atmospheric pollutants, which may later concentrate in runoff streams. Nickel, boron, and lead are or have been used as gasoline additives, while arsenic and mercury are industrial air pollutants (Brady 1984). Other metals identified in the preceding discussion as air pollutants include cadmium and managanese. The U.S. Geological Survey (USGS) has a surface water quality station 50 ft upstream of the Long Island Railroad bridge on the east bank of the Carmans River. This station had traceable levels of lead, mercury, chromium, copper, iron, manganese, nickel, and strontium for the water year between October 1990 and September 1991 (Spinella et al. 1992). This indicates that these contaminants are still being transported onto the refuge and may contribute to the sediment concentrations observed.

CONCLUSIONS

The 1994 sediment residue analysis for Wertheim NWR confirmed and enlarged upon the 1990 and 1991 findings. There is a transport of contaminants onto these refuges. On Wertheim NWR, four areas can be considered depositional areas or contaminant "sinks": the upper Carmans River, the mouths of Yaphank Creek and Little Neck Run, and the full length of Big Fish Creek. The level of metals contamination in Big Fish Creek had not previously been recognized. In addition, elevated levels of cadmium and lead are particularly widespread.

The results of fish tissue residue analysis indicate that forage fish within the Wertheim NWR have accumulated body burdens of arsenic, chromium, mercury, and selenium in excess of levels that pose a risk to predatory organisms. However, the routes of exposure leading to this accumulation is unclear. Fish tissue levels were not correlated to nearby sediment samples, and it is possible that accumulation may be due to dietary sources or deposition of airborne contaminants into the water column. Future refuge studies should focus on routes of exposure and biological impacts of contaminants.

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Appendix A

New York Field Office (DM/KK - 6/92)
(607) 753-9334

STANDARD OPERATING PROCEDURE FOR COLLECTION OF WATER AND SEDIMENT FOR ANALYSIS

Prior to field collection:

1. Prepare labels, Chain of Custody, and Sample Inventory Forms:

   Labels should be simple: include sample ID (8 characters or less) and sample date.

2. Assemble chemically clean sample containers (depends upon tests to be performed and lab specifications).

   One container each for:

   a. Biochemical Oxygen Demand, 500ml water in plastic
   b. Chemical Oxygen Demand/Ammonia, 500ml water in plastic
   c. Sediment-Pore Water Bioassay, 4000ml sediment in glass
   d. Bioassay water (Microtox®), 8000ml water in dark glass

   Two containers each for duplicates for:

   e. Organic contaminant residues, 500ml sediment in glass
   f. Inorganic contaminant residues, 500ml sediment in glass
   g. Duplicate, 500ml sediment in glass

3. Tape labels to the containers to be used for collection, this reduces confusion and work in the field. Wrap tape completely around jar, to prevent loss of labels due to moisture.

4. Sample collection equipment needed:

   a. All stainless steel Ponar dredge
   b. Stainless steel soil auger (backup sampler)
   c. Stainless steel kemmerer bottle with teflon stops
   d. Stainless steel buckets
   e. Stainless steel pans (to set dredge in)
   f. Stainless steel spoons and ladles
   g. Nylon bristle brushes with plastic handles
   h. Water chemistry measuring equipment (dissolved oxygen, temperature, pH and conductivity meters)
   i. Coolers and ice (enough to hold all samples)
   j. Assortment of plastic bags (Ziploc and twist-tie types)

5. DECON of sampling equipment: To be done initially and between each sampling sites:

   a. Scrub equipment with detergent solution
   b. Rinse with water (tap or stream acceptable)
   c. Rinse twice with distilled water
   d. Rinse with 10% Nitric acid
   e. Rinse thoroughly with distilled water
   f. Rinse with acetone
   g. Allow to air dry
   h. Cover with aluminum foil

<u>At collection site</u>:

1. Collect water chemistry data, 3 rounds of readings or automatic readings for a designated amount of time, are suggested. Rinse probes with distilled water after readings are completed.

2. Collect all water samples first with kemmerer just above sediment level or with grab samples taken at least 12 inches below surface. (leave no head space)

3. Collect a composite sediment sample with the ponar dredge or soil auger taking at least 5 grabs and place in bucket, rest dredge in pan while resetting. Try to select a site which has silt or clay sediment type.

4. Homogenize sediment in bucket with spoon or stainless steel auger and cordless drill. Wear disposable gloves and avoid contact with the sediment.

5. Fill sample containers: leaving no head space for bioassay samples and filling maximum of 3/4 for residue samples. Tape cap on with a durable tape then place on ice.

6. DECON equipment between sampling sites (if a base station can be set up, steps 4 and 5 can be done there).

7. DECON and store equipment after sampling has been completed.